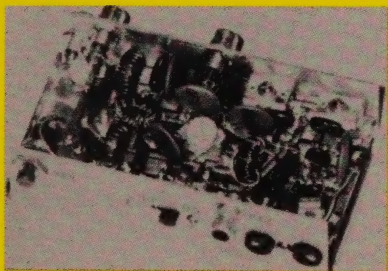


2nd edition

The
JOY of QRP
STRATEGY for SUCCESS



- *Types of QRP Operation*
- *Clubs, Awards, Activities*
- *Planning QRP Operation*
- *Equipment Selection; QRO-QRP Mods*
- *Homebrewing a QRP Rig*
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DEVOTED EXCLUSIVELY TO UNDER FIVE-WATT AMATEUR RADIO

QRP Quarterly

July, 1984 - Volume XXII - Number 3

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SPRAT

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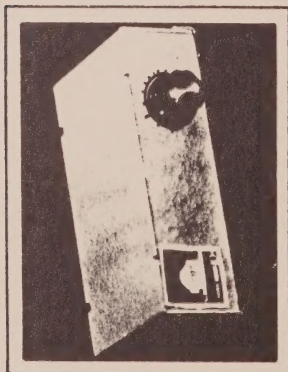
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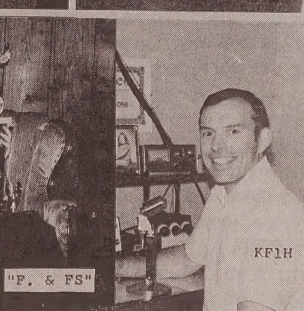


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6/75 LABELS RENEW NOW PLEASE

Gene Pearson AA8MI Aug. 2010



Preface

A book has long been needed for newcomers to the exciting and challenging low power (QRP) area of the amateur radio hobby. Although many articles about QRP have been published during the past decade, they usually haven't addressed the real need. True, they provide many valuable hints about QRP operation, but they don't show the newcomer the overall picture and how to think things out for himself. And that is unfortunate because there are no absolute rules for successful QRP operation. Every operating situation exhibits a unique combination of many variables. These must be analyzed in the context of relevant radio theory in order to decide which rule is right for a given situation. In my many articles about QRP, I've tried to show newcomers what is involved in that process. But a bit here and a piece there really doesn't do the job. Hence this book. In it, I attempt to alert newcomers to the practical factors and those aspects of radio theory that are important in QRP operation, and to show them how to think through to strategies which provide the greatest chance of successful and enjoyable QRP'ing. I hope it succeeds — if it does, the QRP movement will profit from it and many operators will be saved from the "QRP didn't work for me" column.

A word about how this book came into its present form. I began writing it about five years ago, but what I came up with at first was a "pap and pablum" thing that didn't really explain anything. So I tossed that version out and committed myself to the task of addressing the needs of newcomers and veterans alike. What resulted was the massive typescript of **The QRP'rs Guide to Transmission Lines, Antennas, Propagation and DX'ing: The History, Theory and Practice of QRP**, running to 1150 pages with nearly 300 drawings, many of them consisting of multiple curves. Three chapters totaling about 450 pages provided "hard-core" propagation theory and application, most of which has never been seen in the amateur literature before. CQ Publishing had waited patiently for the book, but in the meantime, had initiated publication of a new magazine, and budget and staff were strained to the limit. Rather than wait until things loosened up, I decided to pull out about 375 pages directed at newcomers, and **The Joy of QRP: Strategy for Success** is the result. We'll try to get the rest into print in the next year or so.

Several individuals deserve a word of gratitude for their assistance in this project: Sylvia Wheeler, writer, poet and teacher, for comments on the first chapter of **The QRP'rs Guide**; Walter Maxwell (W2DU), Astro-Electronics Division of RCA, for corrections and suggestions for the antenna chapter of **The QRP'rs Guide**; Robert B. Rose (K6GKU), Head, Naval Ionospheric Assessment Systems, for reading the entire(!) 1150 page typescript, making corrections and suggestions for the propagation, DX'ing and "Planning for QRP Operation" chapters, and permitting me to include one of his previous articles from **The Milliwatt**; Warren Cassidy (KA4RAI) who wrote to me with questions about getting started in QRP, and received the freshly written "Planning" chapter as an answer! — his reactions were greatly appreciated; Marianne R. Schuld, the real "F. & F.S.", for helping in many ways, especially for original artwork (Figs. 13, 15, 16, 18); and to **CQ Magazine** for use of artwork (Figs. 17, 19, 20, 37 and p.c. templates). And finally, to the countless QRP'rs whose comments have inspired and motivated me, my thanks not only for making QRP operation more enjoyable for me, but also for giving a higher purpose and meaning to my enjoyment of QRP. May this book do the same for many others!

Ade Weiss, W0RSP
January, 1985

The
JOY of QRP

STRATEGY for SUCCESS

by

Adrian Weiss
K8EEG/WØRSP

*AC5QV
Raymond - I hope that
you find this
useful -*

*Milliwatt
Books*

526 N. Dakota St.
Vermillion, SD 57069

*Enjoy QRP!
73/72
Ade
WØRSP*

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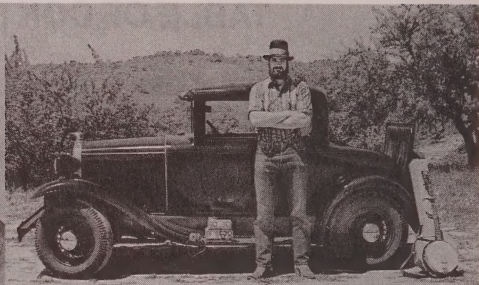
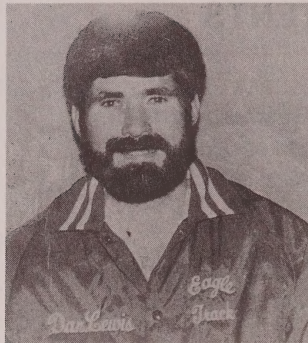
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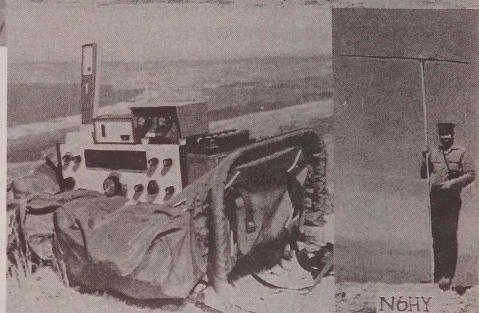
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IN MEMORY
OF
Daniel S. Lewis II
N6HY
(1951-1983)



"Funeral services were held last Wednesday for a popular Templeton High School teacher who died in an automobile accident May 21. 31-year-old Daniel Stuart Lewis II, A Paso Robles native, had been returning from a speaking engagement for the Fresno Amateur Radio Club. He was a member of the Paso Robles Amateur Radio Club and held the world record for distance in low power radio transmissions. Lewis was president of the Templeton Teachers Association and was named teacher of the month in March 1983. He taught auto mechanics and photography at the high school for five years, and also served as track coach. A memorial fund was established in his name with the Templeton Union vocational art scholarship fund. He was a 1969 graduate of Paso Robles High School, and was a Phi Kappa Phi graduate of Cal Poly, San Luis Obispo, in 1978. He also attended Cuesta College. Previously, he served in Viet Nam as a sergeant in the U.S. Infantry."

Tribute from his Students

"He always cared enough to listen. He was never in a very bad mood. He loved to teach — very open-minded, intelligent. He could talk and would talk, about anything you wanted. He will never be forgotten. He will be missed." "Those who knew you as N6HY will miss you also. You were very proud of your low power transmission record. Proud also of the fact that you had attained all the ham licenses possible. Yet you always became very enthusiastic when someone asked about getting started as a ham operator. I knew you were a true lover of your hobby when I saw the license plate on your car — N6HY." "Dan was one of the kindest, most considerate human beings I've known. He was a man to respect and admire!"

Chapter 1

The Exciting World of QRP

We said at the head of this article that a lot of foolish things had passed out of amateur radio (in the U.S.). Now it is the turn of the "ether buster," the "watt burner," and the lad whose ideal in life is to wreck the antenna ammeter! In place of this pest, we will have the NEW AMERICAN AMATEUR, whose ideal is not a BIG station, but a GOOD station, who does not care how far his station reaches but who will try to make it perform as perfectly as possible . . . in the future, the question will be — as ad men say — "Not how much, but how good." — Robert S. Kruse.

I. QRP in the Beginning

Back in the early 1920's, the switch from spark gap to vacuum tube transmitters revolutionized radio communications, especially among radio amateurs. On the one hand, the strict distance/power relationship no longer applied. Multi-KW spark rigs could be replaced by a few watts of c.w. from a vacuum tube transmitter for communications over greatly increased distances with better readability. Second, vacuum tubes could oscillate at far higher frequencies than had ever been used for radio operation, generating r.f. signals up into the then unknown high-frequency (h.f.) spectrum — the "shortwaves." The impact upon radio communications was monumental. And that was when the QRP approach to amateur radio was born.

By 1925, amateurs were regularly communicating across the oceans. Most operators had little choice about their power levels — about all that was economically feasible were vacuum tubes designed for use in receivers. These tubes could manage a maximum of about 10-15 watts input when pushed hard enough to make the plates light up to a red-or even white-hot glow. The highly inefficient circuits in use probably dropped efficiency to 10-20% at best as far as r.f. output was concerned. But the distance records established by low power operators using "five watter" tubes astounded everyone and received much attention in **QST** and other magazines. Then, as now, many of these low power operators asked: "If I can do it with that much power, why not with less?" That is where the QRP approach began. And the distance/power records established in those early days are all the more incredible when we consider that primitive regenerative detectors were the only receivers in use at the time. But something happened to lift the QRP approach from a grass-roots phenomenon to a highly visible, quasi-official status in the U.S.

During the winter of 1923-4, an Australian operator, C.D. Maclurcan, "a2CM" (then-current VK call-sign prefix), had sailed across the Pacific with one purpose in mind — to discover why the signals of Australian and New Zealand amateurs could not make the same trip via the ionosphere. The "down-under" operators had been copying hundreds of American signals during the fall months, and were perplexed by their inability to establish two-way contact. The American signals were a constant source of amazement to them, and Maclurcan complimented American amateurs: "Our hats are off to you fellows." He didn't know the truth. He maintained contact with Australians during the entire Pacific crossing, and worked them with 10 watts input from shipboard in San Francisco Bay — while no American amateurs could even copy their weak signals! His first visits to American stations revealed the truth behind the strong American signals heard in Australia. While Americans described their power only in terms of the tube-rating, and many used "150 watter" and "250 watter" tubes, they were pushing as much as

10kW into them! What resulted was predictable. As Maclurcan noted: "The QRM at amateur wavelengths is, at all times, indescribable." The reaction at the American Radio Relay League headquarters (ARRL) to Maclurcan's findings (published in the Australian magazine **Radio**, May, 1924) was fierce: "Well, fellows, the Australians have us sized up as a bunch of 'duds' when it comes to shortwave reception . . ." And **QST** Technical Editor Robert S. Kruse spelled out the implications for American amateur radio in his "The New American Amateur" article in the August, 1924 issue. The passage quoted at the beginning of this chapter is from that article, and gives some idea of the lambasting he delivered to the "ether busters" and "watt hogs." And to back up the rhetoric, Kruse placed stronger emphasis upon the low power tests which he'd begun in 1923. In fact, in the next published report of results, he included two high power stations whose "records" figured out to about 5 miles-per-watt, ludicrous in the context of those submitted by real low power stations running under one watt input. In short, the QRP movement became associated with the idea of the New American Amateur in **QST**, the official publication of the American Amateur Radio Relay League.

The New American Amateur was a combination of technical knowledge and practical skill: (1) he applied the principles of low-loss and efficiency to the design, construction and operation of each part of his station, including receiver, transmitter, feedline, and antenna; (2) he acquired the most current knowledge about antenna operation and propagation phenomena and applied that knowledge to his own station; and (3) he aimed for a high degree of skill in operating his equipment in making two-way contacts. While Kruse intended him as an ideal for all amateur operators, he introduced the New American Amateur in a specifically QRP context, and stressed the fact that a superior operator with an efficient station and low-to-moderate power can embarrass the slipshod operator who relies upon high power to cover his ignorance and lack of skill. For the low power operator, the ideal of the New American Amateur is utterly essential to his success. As a result, QRP operation is for the kind of amateur who will dedicate himself to acquiring the knowledge and skills that are necessary to offset the 20-40dB power disadvantage that QRP operation involves. He is the kind of amateur who rises to a challenge because it provides him with an opportunity to improve himself, both as a person and as an operator. He is the kind of operator who is satisfied with nothing less than the feeling that his knowledge and expertise are the critical factors in his success. Ultimately, after much work, the newcomer to QRP can become such an operator, but it is not easy — if it were easy, QRP would be unable to provide the most unique satisfaction and sense of pride that is available in amateur radio. And QRP operators would not be held in high esteem by the amateur fraternity, as they now are because QRP is difficult and because it is a great challenge. The rest of this book attempts to show newcomers to QRP what it takes to attain the full enjoyment that low power work can provide.

II. The Enemy — Frustration.

In introducing modern amateurs to low power work, the most important point that I can make is about the role of frustration in the QRP experience. KW's and crowded bands can make life difficult for the QRP operator, but they won't kill him. Frustration can conquer him utterly. Ironically, this psychological enemy is created by the QRP operator himself. It is crucial that the newcomer to QRP understand this fact. Psychologists have long known that frustration is caused by an individual's failure to transform his expectations into reality. Actually, this is just plain common sense. An example or two will help clarify the operation of the expectation-frustration syndrome. If Joe expects to attain a 32 mpg efficiency ratio with his automobile, and he repeatedly ends up with 23 mpg, no matter how many trick adjustments he makes or how many gadgets he hooks up, Joe obvi-

ously ends up quite frustrated and angry. Likewise, the QRP operator who expects to work DX stations at every sitting, even though his HW-8 is only putting 1.2 watts into his vertical with four radials, will end up totally frustrated. Both Joe and the QRP operator commit the same flaw in their thinking processes, and that flaw locks them into the expectation-frustration syndrome. Quite simply, their expectations exceed the limits imposed by Nature's laws upon the phenomena which they are attempting to manipulate. In other words, they are expecting to achieve objectives that are either impossible, or at best, highly improbable.

Now, if you nod in agreement with the previous statement, you've just been caught in the same logical flaw that the examples are designed to illustrate. You agreed to a statement made upon the basis of insufficient information or knowledge. For, if Joe's engine displacement and carburation is such that a 40 mpg ratio is possible, there is no reason why he can't realize his expectation of 32 mpg. But, if the maximum possible ratio for that engine is 26 mpg, then the statement above is true. Similarly, if the DX that the QRP operator expects to work is strictly Caribbean stuff 1500 miles away, he certainly can realize his expectations. But if he expects to work 5000 mile DX, then it is highly improbable that he will succeed. The point of this tricky example should be apparent — before the individual can judge the viability of his expectations, he must know the limits imposed upon the phenomena involved! He must have the necessary information! If he does not possess that knowledge prior to setting up expectations, he makes himself vulnerable to failure. Expectations, in short, must be based upon a realistic assessment of a situation and the laws governing it.

Of course, the beginner cannot be expected to know all the theory and data needed to establish realistic expectations. Hopefully this book will provide him with a headstart in the right direction. However, attainment of the necessary knowledge must be the beginner's priority goal and he must be absolutely patient in seeking that goal. Great exploits with QRP can come later, just like the high paying job can come only after four years of college. QRP operation is not simple — sure, once an operator becomes an expert, he makes it look simple, but he has a great deal of expertise underlying his efforts, and that's why he makes it seem easy. The QRP operator ultimately must learn about and develop an intimate familiarity with many principles and phenomena that the high power operator need never even think about, let alone be familiar with. Let's take our QRP operator from the earlier example, and briefly discuss what he can learn about to establish a more realistic expectation for his situation.

The primary consideration is: given his power output to his antenna, what strength can his signal be expected to develop at the terminals of a receiver 5000 miles away under optimum propagation conditions? First off, he must determine his actual r.f. output on 14 MHz — if 20% of his 1.2 watts is actually 28 MHz second harmonic radiation, it won't help him on 14 MHz! Next, the loss factor of his feedline-antenna can be determined by checking the condition of his feedline, determining the feedline loss for that brand simply by checking charts in various handbooks or by measuring it, and then calculating the r.f. power which the feedline delivers to the antenna. Another check of the charts and graphs in antenna handbooks will provide him with a reasonable estimate of the efficiency of his vertical-plus-four-radials antenna system. He'll be in for a disappointing surprise when he finds out how much of the power delivered to his antenna is wasted! What is left, of course, is the actual power that is radiated from the antenna. With this amount of power established, another glance at monograms found in the literature will provide a ball-park estimate of his signal strength by using relatively simple formulas. It might be a good idea to recalculate for different conditions. Things may look promising at this point, but one final check is necessary — given the angle of radiation from his antenna, will his signal even exhibit a "skip zone" at the distances he wishes to work? After all this checking, the final context must

be added — will his signal strength have a chance of competing with others that are 20-40dB stronger? Without going through all the calculations for this example, it is reasonable to observe that this operator's chances of working 5000 mile DX are extremely low, even with optimum propagation conditions. Hence, to establish the expectation of working that distance will inevitably result in a high degree of frustration, and perhaps result in another potentially good QRP operator biting the dust.

Now, with all this said, what is our newcomer to do? First, he can establish more realistic expectations, such as aiming for a 65% call-contact ratio with stations out to 2500 miles, and a 35% success ratio at 3500 miles. He will have a good chance of attaining the primary goal, and the secondary goal will be a real challenge. During his successful pursuit of the primary goal, he will gain invaluable experience as an operator and attain a greatly increased familiarity with propagation phenomena, and while doing this, he will be enjoying every moment and gaining confidence as he develops into a good QRP operator. Or, he can decide that DX is his bag, study up on high-gain antennas, find one that will provide a 6-10dB gain when tuned properly for maximum forward gain (the QRP's way!), and then go to work hunting DX. He'd probably be better off in the long run taking the first option above, for it will provide much more experience in actual communications skills as they apply to QRP, and then when he converts to the big antenna, he'll be ready. Incidentally, the above example is not all that hypothetical — I'm describing my own entrance into the world of QRP DX'ing via the second option. A few details are modified — my transmitter generated 700 milliwatts r.f. output and the antenna exhibited something on the order of 4dB gain.

My own experience is no different than that of most QRP beginners. During the past decade or so that I have been writing about QRP operation, I have had thousands of letters cross my desk voicing frustration because QRP operation wasn't turning out as it was pictured in my writings. In most of these cases, unrealistic expectations and a lack of understanding of what was happening was the source of the problem. To cite one typical example, a newcomer with about four months experience wrote from Colorado asking if I could figure out "what was wrong" in view of the fact that, with one watt into a 40 meter dipole at 20 ft. his call-contact ratio was a miserable 10% and he just could not work out of the "O" call area regardless of how many times he tried. He had gone over his entire system with a fine-tooth comb several times (his words) in the hope of discovering the culprit, but everything seemed to be working properly. Actually, nothing was wrong with his system. I asked him to check his log and determine whether his successful contacts spread along a circle drawn around his location with a radius of about 400 miles. Further, I told him that I suspected that his operations occurred primarily before darkness, and explained the relationship between antenna height vs. angle of radiation and one-hop skip distance, expected loss vs. a one watt signal on its journey to the second skip zone, and suggested he analyze his situation along these lines. A couple months later, I received his reply, which was in an entirely different vein than the first letter. Once he understood that his system was doing all it could be expected to, he accepted 400 mile contacts as his goal, spent most of his time calling close-in stations rather than wasting time on the "9" and "8" stations he heard, and was working most of the stations that he called. Nothing had changed except his understanding of the situation and his expectations — and it turned QRP operation from a frustrating hassle with no rewards into a very satisfying experience. Finally, he had decided to get his antenna up off the lawn and work some east coast material as soon as he had time. I was pleased. Everytime I get such a letter, I have a nervous reaction just like a doctor who wonders if he'll get there in time to save the patient. Sometimes I do, and then there are other times . . .

In editing operating reports for publication in **The Milliwatt** and **CQ**, I have often been tempted to head off mistaken impressions that reports can create. I have never done so, so I'll do it now. The point is: when an operating report communicates an operator's excitement at his successes and states that QRP operation is "so easy", remember one very important fact: he is able to write such a report only because he has mastered the knowledge and skills that are so necessary for successful QRP operation. Remember that this operator was once a beginner in QRP, and at that time, he was frustrated and baffled as to why he couldn't duplicate the successes that he had read about in operating reports! We all enter the world of QRP as beginners and must piece together the knowledge and skills to operate QRP with success. But it is worth the effort, believe me!

III. QRP's Unsung Heroes — The Other Guys

The appearance of a QRP signal on the bands is not an event redounding merely to the expertise of the QRP operator. Indeed, without conscientious, skillful operators "at the other end" of the communications circuit, a QRP operator's life could be very dismal. The QRP operator must never forget this! He is grateful to the guy on the other end for putting in the effort to pick his weak signal out of the QRM and make the contact a success. The great contribution of QRP to the amateur radio hobby lies in the fact that it brings out the best operator qualities at both ends of a contact.

The challenge of QRP is two-sided, and often the QRO operator at the other end becomes more determined to make a contact a success than the QRP'r himself. I've had this happen to me many times. A successful QRP contact forms a bond between two operators like no other type of contact, because both know that success is entirely dependent upon their skill when the going gets rough. And both can feel pride in their skills when the final "SK-dit-dit" is transmitted, because they have successfully and cooperatively challenged Nature's limits and won! Sure, the QRP operator is the one who gets all the glory for outstanding low power work, and this is definitely unfair to all the unsung heroes out there who are, in large part, responsible for QRP accomplishments. I've tried to figure out some way to offset this unfairness, but I haven't come up with a method. About eight years ago, I tried to create an award for these top-notch operators on the other end and provide them with the recognition that they deserve. But it was a very impractical award. What I didn't realize at that time was that these operators on the receiving end had all the recognition and satisfaction they needed just from the experience itself. I realized that after going through stacks of QSL's submitted in application for DXCC-QRPp and DXCC-Milliwatt. A solid 70% of these cards included excited comments by the receiving operators that indicated that they too got a thrill out of pulling off the successful DX contact! They experienced the thrill of QRP on the receiving end, and they were proud of their role in the successful contact. And for good reason! Someday we may have a QRP convention, and we'll all sort through our logs and compare notes on the "other guys" and come up with an Honor Roll of the top-flite receiving end operators who repeatedly make our successes possible. Those of us who have operated the DX contests with QRP for a while know who the really outstanding DX operators are. They pull our mini-signals out of DX contest pile-ups on our first or second call everytime. They can copy "QRP" when it is buried 40dB under the wolfpack. Their brains seem to be programmed for it. They pay us the ultimate compliment by interrupting their five-per-minute QSO runs by "QRZ QRP" and then wasting valuable time copying us, giving a report and congratulating us on daring into the sport of the KW's with a meager five watts! And their QSL's reappear in application after application for DXCC-QRPp and DXCC-Milliwatt. My respect for these DX operators on the receiving end is unlimited — they are the elite of the world of radio! There ought to

be some way of letting the world know. The next time you hear a fast-running DX station "QRZ QRP" during a pile-up, or question "QRP?" during the exchange, mark that DX station's call, for he is one of the best! On behalf of all QRP operators, I applaud all you receiving operator who put in the extra effort make our low power work successful, I thank you; and we are grateful, for without you, we wouldn't we wouldn't have much of chance!

IV. Types of QRP Operation

Now that we've covered the philosophy underlying QRP operation, let's get down to practical matters. The great thing about QRP operation is that it does not require any special equipment — any existing transmitter or transceiver can be used at low power levels. QRP can be used in any specialized area of amateur radio — except for e.m.e. moonbounce work, of course — and even s.s.t.v. operators have managed to work long lists of countries on QRP! For example, between February and November, 1974, WB4OVX had worked 35 states and 7 countries with his s.s.t.v. Argonaut, never using high power to initiate contacts. On one occasion, he reduced output to 1/8-watt and maintained perfect visual transmission over a 700 miles path. His comment: "I did not think I had a prayer, but believe it or not, I read the 1/8-watt frames when he sent them back to me. That was hard for me to believe!" Since then, other s.s.t.v. operators have turned to QRP and attained great successes. I mention this in passing to stress the fact that QRP can be used in any mode of operation and any type of activity.

And to top that off, the economics of QRP is the same as back in the 'twenties, when writers continually reiterated that QRP is not a rich man's sport, but affordable to all. Going the QRO route means a minimum of \$600 initial outlay just for a good transceiver, to which must be added accessories and the like. A brandnew Argonaut 515 cost under \$400 and it included every feature that a used QRO transceiver has EXCEPT it will only generate about 5 watts output. Excellent used units are available for under \$300. A used HW-8 will set you back about \$120! Personally, I like a "good deal", so I scrounge the want-ads in the ham magazines for used equipment. One recent newcomer to QRP was using an old DX-20 c.w. transmitter for QRP when a local friend offered him an "oldie but goodie" Hallcrafters HT-18 all-band v.f.o. for a minimal price. It just so happens that the HT-18 is capable of putting out 3-5 watts on all bands — a perfect QRP rig! We'll discuss these methods of getting started in QRP for your particular economic level later in this book. For now, let's discuss the various types of operation that QRP operators are drawn to.

As I noted, one can operate QRP in any mode with existing high power equipment. Most modern transceivers are capable of operating at QRP power levels through a simple adjustment of the gain control. As a result, quite a few fellows are part-time casual QRP types. Bored with the ease of working QRO, they get to fiddling around with the power output capabilities of their rig and discover that, according to their in-line wattmeter, they can decrease output to QRP levels. Naturally, once they have it there, they decide to see if they can work anyone. WB2ISH described his own approach this way: "I run a TR-4C sans linear and a 4BTV vertical, ground mounted. Just for fun I'll load the Drake to maximum output, and then with the use of my wattmeter, I cut back the power to where it shows 5 watts going out and a trifle coming back. I get a real kick out of latching onto a QSO this way." Often an operator will require a QRO rig for his major interests, such as traffic or emergency work, and cannot afford a separate QRP rig. This part-time approach is perfect in such a case. But a word of warning: if you try it this way, beware that the QRP bug may bite! In that case, you'll eventually put all your time into QRP work, and end up selling the QRO transceiver. This has happened

to thousands of fellows who thought they could be satisfied with an occasional kick like WB2ISH and found themselves completely hooked! This is no exaggeration.

The path into QRP operation often involves QRO operators who have spent years chasing various awards with high power, and once that becomes too routine and easy, they decide to start chasing awards all over again, but with 5 watts output. This is especially true of ARRL DXCC Honor Roll operators who are near the top of the list. During the boredom of weeks and months waiting for the next DX'pedition to put a new country on the air so that they can add to their countries totals, they decide to see what kind of DX they can work with QRP. Given their skills and antenna systems, working DX with QRP is quite easy for them, and they embark upon their new-found quest for DXCC-QRPp. K8MFO completed the task in a mere 56 days and became the proud owner of DXCC-QRPp Trophy #3.

In an article in **SPRAT**, quarterly journal of the G-QRP-Club for Spring, 1979, Chris Page (G4BUE) told his story which is so typical of so many:

*"Three years ago I would never had said that G4BUE and milliwatts would go together. At that time I never dreamt of using less than 150 watts d.c. or 400 watts p.e.p., as the case may be, as I sought to add new countries to my DXCC or took part in the many contests which I entered. Although I have retained my interest in both DXCC (260 confirmed) and contests, I have now added QRP to my interests. Since August 1976 (when I started using QRP), I have progressed via an HW-7 and HW-8 to an Argonaut, which gives 5 watts input on 80 through 10 metres. During that time I obtained DXCC-QRPp #8 issued by **The Milliwatt** and was just wondering what to do with all my spare time now that the hundredth QSL had arrived, when I read the article in the Autumn (1978) **SPRAT** by Brice Anderson, W9PNE — "Inter-continental QRP QSO's using milliwatts" — the guy must be mad, I thought. Brice's article caught my imagination, and as **The Milliwatt** also offers a DXCC-Milliwatt for 100 countries confirmed whilst using an output of 1 watt or less, I decided to see if the idea of working DXCC with milliwatts was possible." By December, 1979, G4BUE became the proud owner of DXCC-Milliwatt Trophy #3, convinced that working DX with milliwatts was entirely possible. Since then, he became the second individual (December 31, 1980) to qualify for the DXCC-200-QRPp Plaque.*

Believe it or not, a large portion of the amateur population is interested in plain old rag-chewing, despite the impression that the amateur magazines give that amateurs all are frantically chasing awards or trying to win contests and the like. These operators are not interested in working great distances. They are interested in meeting other operators in a personal context and becoming good friends over the air. This is a very satisfying type of amateur operation. And QRP will make it even more enjoyable, provided that the operator picks his band and time of operation carefully. But picture painted by the magazines is true of quite a few amateurs. There must be ten-thousand awards available to amateurs for working just about every imaginable combination of stations or places. DX work is nearly at the top of the list for award chasers because it involves great distances and a lot of competition. The ARRL (American Radio Relay League) has a complete awards program, and **CQ** offers another series, including the coveted WAZ (Worked All Zones) and the tedious USA-CA "worked all counties" award. The QRP-ARCI (QRP Amateur Radio Club International), the Michigan QRP Club (MI-QRPC), the G-QRP Club, and other foreign organizations offer awards specifically for QRP achievements, and we'll provide a description of these awards in another part of this chapter. In general, chasing an award is much more rewarding with QRP because the basic idea of an award is that it provides a goal that is challenging. Anything that is a challenge with QRO is moreso with QRP! This should be obvious. Award chasing is an excellent activity for developing the skills and knowledge that a QRP'r must master. This is true chiefly because working for

an award requires analysis of the approach, attention to details, formulation of a long-range strategy for working toward the goal, and finally, learning the virtues of patience and persistence.

NET operation is another type of activity pursued by QRP operators. Basically, a NET is simply an organized on-the-air activity with some predefined purpose, with meeting times and frequencies arranged and publicized in advance. Some NETs handle messages, others maintain a round-the-clock alert for emergency medical situations, and others have less noble purpose such as award-chasing and rag-chewing. Several QRP organizations maintain NETs specifically for QRP operators. The basic purpose of the QRP NET is to provide an opportunity for QRP operators to meet each other on-the-air, test QRP equipment and antennas, and exchange information as well as signal reports. The most up-to-date information about QRP NET schedules is found in the newsletter of the sponsoring organization.

Contesting is another favorite activity of QRP operators because of the challenge involved. Generally, a contest is a competitive activity with scoring based upon the number of stations worked multiplied by other selected factors, such as power level used, number of countries worked, number of states worked and the like. Every contest has its particular set of rules which usually can be found in the "Contest Calendar" of **CQ** magazine, where the latest information about scheduling and rules are published by **CQ** as a service to subscribers. At present, there are several contests especially for the QRP operator and these are sponsored by organizations such as the MI-QRPC, G-QRP-C, QRP-ARCI, The DL-AGCW, and others. A listing will be provided below of these special events. The general contests that are most popular with QRP operators are the ARRL Field Day during June, the ARRL Sweepstakes during the fall, and the two DX contests in the spring. Responding finally to the popularity of QRP operation in these DX contests, the ARRL instituted separate QRP sections. The Field Day activity has always had a QRP section, and back in 1970, **The Milliwatt** attempted to encourage the participation of QRP operators by instituting the **Milliwatt Field Day Trophy**, which is still being awarded in memory of **The Milliwatt**. More recently, the QRP-ARCI and MI-QRPC became joint sponsors of **The Milliwatt's** Field Day program. It will be described below. The four big DX contests sponsored by **CQ** were the first to initiate a separate QRP section with scores listed separately and a trophy to the high scoring QRP entries. Participation in these QRP sections has been enthusiastic since their inception. The top-scoring scoring stations have alternated between the U.S. and foreign countries, indicating that the Americans can now compete — the **QST** staff of the 'twenties, Kruse, Hatry and Warner, would have been proud! Contests are, of course, the supreme challenge of an operator's skill and endurance, especially when he is running 1 watt or so and competing for contacts with KW's! We will devote a later chapter to a discussion of operating strategies for several of the most popular contests (see Chapter 7). QRP DX'ing is perhaps the supreme challenge for QRP operators and attracts great numbers of QRP operators because it involves all the challenge and fulfillment, as well as frustration, that is inherent in QRP operation. DX'ing is the ultimate test of an operator's skill, as well as of the efficiency and effectiveness of his station. While several QRP organizations offer DX awards for working various numbers of countries, QRP DX'ers aim at qualifying for THE DX awards: the DXCC-QRPp Trophy for working 100 ARRL countries with less than five watts r.f. output, or the DXCC-Milliwatt Trophy for doing the same with less than one watt r.f. output.

These awards were initiated in 1971 by **The Milliwatt**, and continue to be offered at present, to encourage QRP operators to show that QRP is effective in DX work, and to place their achievements in direct comparison with the ARRL DXCC award, which has no power limit and is usually won with power levels of several hundred to a thousand watts. The same stringent ARRL rules are applied

to the above QRP DX awards. It is amusing to find the ARRL publications describing their DXCC as the most difficult award in amateur radio! The holder of one of the above QRP DX awards gains membership in the most elite group of operators in amateur radio. To date, 67 individuals have qualified for DXCC-QRPp, while only 9 have qualified for DXCC-Milliwatt! In addition, 6 individuals have qualified for the 200 countries-confirmed with 5 watts output, and W8ILC is the only amateur in history to pass the 200 and 300 countries marks with less than one (1) watt output! At present, he has confirmed 300 countries with less than 1 watt output. See below for details about these awards.

The miniature size of QRP equipment has led to the great popularity of portable QRP operation, since the average solid-state QRP transceiver can be powered by lantern batteries, a group of C-cells, or solar cells. As a result, QRP operation is possible from any spot on the globe accessible to man. The adventure inherent in communicating with the world from a remote spot far removed from commercial power has sparked imaginative efforts by many QRP operators to design their own special miniature equipment for such ventures. The latest in a series of such miniature transceivers, the "Viking 3x5", was featured in the May and August, 1980, issues of **CQ**. It measures just 3 x 5 x 1.25 inches — smaller than a paperback book — develops 4 watts output on 14 MHz, is v.f.o. controlled, with a very sensitive receiver featuring a high degree of audio selectivity. Other designs by W7ZOI, W1FB, K6EIL and W7BBX, to mention a few, have appeared in recent years. I've operated QRP in many different types of activity, but for my money, portable operation is the most exotic type of QRP operation. There's nothing like it! But my experience with QRP portable is rather mundane — state parks, easy mountains, field, etc — in comparison to more adventurous types. W6JTH is perhaps the most famous and adventurous QRP'r. His other hobby is mountain-climbing, and he has spent several days of each summer scaling western U.S. peaks, setting up camps on rocky summits, and operating Field Day with his trusty HW-8, using dipoles whose height was limited only by the climbing poles that he used in making the ascent! Pictures of his various set-ups have appeared in **The Milliwatt**, **QST**, and **CQ** over the years. He has to be the ultimate portable operator!

QRP's portable potential has often been joined with an operator's camping and hiking urges. For example, WB9LKC's favorite vacation activity is canoeing the Boundary Waters Canoe Area in Northern Minnesota with his young sons. This area is a virgin paradise, as those who attended WB9LKC's slide-presentation at the Dayton Hamvention QRP Forum several years can attest. After having stumbled onto QRP operation, WB9LKC decided to try taking along a QRP transceiver to maintain contact with the outside world, and his big question was: "would contacts be possible, or would the rig turn into excess weight. No fun portaging extra weight!" The use of the QRP rig was a big success, and he told about it in his story "A Canoe, A PM2B, ES QNI QTC QRPp 9/0" in the June, 1976 issue of **CQ**. Then, back in the early 1970's, WA8DDI got his kicks by running one watt to a 30 ft. vertical in a rowboat in the middle of a lake! A picture of his set-up appeared in the May, 1974 issue of **CQ**. Rowboats are one thing, but WB7BZR lives on an ocean-going sailboat, and has been attempting to work all states using an Argonaut with the riggings as an antenna! At last report, he had worked 37 and confirmed 32. This is definitely one approach to QRP operation that I would like to try, since I'm a sailing nut myself. (Who am I kidding with "I would like to try" — what I wouldn't give for the chance!) Back in '74, a couple QRP operators took a rig along on a backpacking trip into the Grand Canyon — they didn't have too much success getting out. It seems that it is one thing to get a signal off from a 14,000ft peak, and quite another to make it out of a quarter-mile deep canyon! To summarize, there seems to be a principle underlying portable QRP operation, and it is: if the place is there and you can get to it, operate from it.

The low-voltage, d.c. power requirements of solid-state gear makes it especially valuable for emergency operation and operation from remote locations. The a.c. mains can be knocked out by natural disasters, and generators can break down. Batteries are everywhere, though! Adventure is not the only reason for QRP operation from out-of-the-way places. For OA8V, stationed for several years deep in the jungles of Peru, where the only contact with the outside world was via a bush pilot and amateur radio, his Argonaut became a crucial link with the outside world during periods when the a.c. generator malfunctioned, and at times, OA8V found it necessary to pass vital traffic to the U.S. relying solely on the Argonaut — shades of the Hamilton-Rice Expedition (1925-1926) up the Amazon. OA8V's story "Jungle Flea Power" in the April, 1977 issue of **CQ** is perhaps one of the most famous accounts in amateur radio. His discovery that the Argonaut could be relied upon for DX communications led him into the quest for DXCC-QRPP, and he qualified for Trophy #6 as a result, as well as attracting many of the operators that he worked to QRP themselves.

Furthermore, the portability of QRP gear makes it a logical companion for many amateurs whose profession keeps them on the road, with short business trips around the U.S., or better yet, to exotic overseas DX locations. An entire station can be carried along in a small piece of luggage, or spread through other luggage. Most QRP operators dream of being the hunted after rare DX station with everyone begging for a contact! Operators who are lucky enough to mix business and hobby can realize this fantasy. K6SGD, for example, operated as EI7CJ for about a month during a trip to the "old sod", and W7ZC, who has operated from many portable locations during his long amateur career, took along a rig on a vacation trip to Hawaii. During a business trip to Canton Island, KH6GB managed to squeeze in about 25 hours of operation and worked a total of 1150 stations in 35 countries! That is a phenomenal number of contacts even for a QRO DX station — and he did it with an Argonaut! But these lucky ones are in a small minority — many QRP operators find their nights in distant motels livened up by the QRP rig they've brought along, and there are quite a few motel managers across the U.S. who are probably still wondering "what the heck the guy in #38 was doing with that wire hanging off the balcony?"

But the traveler doesn't have to wait until he gets to a motel for the QRP fun to begin. Operating QRP in an in-motion vehicle is in itself an extraordinary experience. Believe it or not, QRP mobile operation is not only possible, but highly reliable. When I first tried QRP mobile operation to relieve the boredom of periodic 9 hour trips across the barren wastes of South Dakota, I really didn't expect to work anybody — mainly just to listen in on the bands and see how conditions were. I was astounded to discover that my 2 watts to the Hustler whip let me talk my way across the entire state on both c.w. and s.s.b. on 20 meters! It was fantastic, and I put in more time operating during the trips, than in the three weeks previous or following them. I really shouldn't have been surprised, though, because the first QRP mobile that I had worked was K4FS who has logged over 500,000 operating miles with a total of over 100 countries, all continents, and all states — while running less than 10 watts input. K4FS had the bright idea of eliminating the dynamotor supply by hooking the plates of his final amplifier directly to the auto battery. In 5 years of operating with 40 milliwatts input, he logged over 5000 contacts! I was among them, as I worked him several times while he was at that power level. The only real drawback to QRP mobile operation is universal — ignition noise is a definite problem, but various handbooks describe the standard methods of eliminating that problem. Some hints appear in Chapter 7.

V. QRP EXPERIMENTS

In addition to using QRP simply as an alternate to QRO in the many types of amateur operating activities, some QRP operators, like Maclurcan, conduct experiments with low power levels as a scientific investigation of Nature's limits. We are all curious at times as to "how low can I go" when we get a good signal report with 3 watts output. Experimenters decide that they want to find out, find some colleague at a distant location, and arrange tests. Or, an experimenter, lacking a comrade at some distant location, measures his results by the number of states or countries that he is able to work. Brice Anderson (W9PNE) is one such individual who decided to see what he could work at various levels below one watt input back in the early 'seventies. His first goal was Worked All States with 500 milliwatts input, using a longwire dipole 465 ft. long, center-fed with 40 ft. of open feedline, with an average height of 40 ft. A 4BTV vertical was later added. By January, 1975, he had completed his WAS with 500 milliwatts. In the next three years, he had accomplished the following results in the operating time that he could squeeze into a very busy schedule.

INPUT	CONTINENTS	STATES	COUNTRIES
500mw	all	all	36
250mw	5	46	16
150mw	2	34	5
100mw	2	33	4
50mw	1	16	2
25mw	1	2	0

Brice notes that, after working at milliwatt levels for a while, going back to 5 watts is like switching from 5 watts to high power! Quite a few fellows have been inspired by W9PNE to test at milliwatt levels as a sideline to their regular "high power" QRP work at 5 watts. G4BUE is one such individual, and he has managed to work 17 countries with 500mw, 12 with 350mw, 9 with 250mw, and 7 with 150mw. Operating skill and patience are at a premium in such work, since the contacts can be few and far between! But a guy just has to find out what he can work! That is part of what QRP is all about.

The other type of experimentation with QRP is a much more organized approach, with regular schedules and super-low powers. To succeed in this type of experimentation, a scientific approach is required with considerable reliance upon theory and math. It is the ultimate test of operator knowledge, familiarity with Nature's signs, and application of theory, as well as a great deal of painstaking construction and instrumentation. The all-time champs at super-QRP work are KL7YU and W7BVV who, back in 1970, managed to establish what may be the never-to-be-broken record of 1.6 billion miles per watt! The record was established over the 1650 mile path between Portland, OR and Fairbanks, Alaska, on January 21, 1970, at 1320 (local time) on 28760KHz. During the record test KL7YU's one microwatt signal was an actual 539 at W7BVV! Maclurcan would have been proud of these two. Kruse would have used them as examples of the New American Amateur. The contact was not a "freak" but was the result of an incredible amount of work. Theoretical calculations indicated that the contact at one microwatt was possible, but only with optimum antenna systems designed for this specific path and an anticipated F2 ionospheric layer height of 320-330km. This led to the selection of a rhombic transmitting antenna at KL7YU, and a terminated Vee beam at W7BVV. The rhombic had an estimated gain of 15-20dB and angle of radiation of 8-12 degrees. Once initial testing progressed, it became apparent that the actual F2-layer height was about 350-360km, rather than the anticipated 320-330km. With respect to instrumentation, receivers at both ends of the circuit were calibrated in "decibels below one watt" to provide an immediate

indication of the relationship between the received signal strength and the given transmitted power, and the ultimate noise floor level of the receiver. For example, if KL7YU's 100mw signal produced an S-meter reading of -90dBw, and the noise floor of W7BVV's receiver was -148dBw, W7BVV could inform KL7YU to decrease power immediately by a factor of 58dB. Thus valuable time in a test situation was saved, when optimum conditions may last for under one minute to up to 20 minutes. To aid in the actual test situation, the path loss was calculated for varying propagation conditions, from near-perfect to less-than worthwhile. Just by referencing the received signal strength to the calculated optimum condition loss figure, band conditions could be determined on the spot. Needless to say, KL7YU and W7BVV could never have succeeded without all the work that they invested in the test — they did their homework, and when Nature relaxed her limits to their minimum, they succeeded! Details of their story are published in the June, 1970 **Milliwatt**.

Several other teams have scored impressive victories against the limits on the power vs. distance relationship. During the course of regular schedules with high power, W6OA and W1WMK decided to see how low they could go and still maintain contact. Conditions appeared optimum on March 21, 1970, and at 1925Z, a 21,009 KHz signal of less than one milliwatt spanned the distance from San Francisco to southern New Hampshire. W6OA's output measuring capability did not permit determining how far below one milliwatt his output was, so the record stands at approximately 3 million miles per watt! More recently, OZ4LP and his group teamed up with WB2OZW for transatlantic QRP experiments. On-the-air contacts led to a personal friendship, and WB2OZW was recruited to the U.S. transmitting end of the circuit. OZ9FS, an engineer-in-charge of satellite communications, had been interested in very-low power work for several years before deciding to challenge the Atlantic. Painstaking attention to detail on the receiving end was the major strategy used by the team. A bandwidth of 5 Hz was selected in combination with a 400 Hz 8-pole crystal filter for the tests. At the smaller bandwidth, extreme frequency stability is absolutely necessary in both receiver and transmitter. For the transmitter circuit, a crystal oscillator followed by three buffer stages fed a driver-final adjusted for one watt r.f. output, with a 21dB attenuator built into the transmitter for decreasing power without affecting the load upon the oscillator stage. A 5 Hz bandwidth, further, is usable only with very-slow code speeds, and to control this dimension, a special automatic keyer designed to send the letter "H" with selectable timing of the dots at 0.5, 1, 2, 4, and 8 seconds, was built into the unit. For unknown reasons, the transmitter constructed by OZ9FS and delivered personally to WB2OZW exhibited a drift rate of 40 Hz per hour, even though a sister unit in Denmark exhibited a mere 2 Hz per hour drift rate. Tests were set up for Christmas of 1975, but WB2OZW couldn't resist temptation with the QRP rig sitting on his operating table, so he worked WA0BWM at the -21 dB level on December 6, 1975, an output of slightly under one milliwatt. During the actual transatlantic tests, the drifting transceiver prevented success for four days, but the team finally succeeded on December 28, 1974, bridging the Atlantic with an r.f. output of 10 milliwatts. Given the gain of the quad antenna used by WB2OZW, the effective radiated power of the 14005 KHz signal probably was around 30-40 milliwatts. Due to the drifting of the transmitter, it was necessary to resort to the 400 Hz receiver bandwidth and a higher code speed than was possible with the build-in keyer. In other words, a great degree of selectivity was sacrificed, and the achievement could have probably been accomplished with under one milliwatt had it been possible to rely upon the 5 Hz receiving bandwidth.

Successful tests by one individual usually result in other individuals attempting their own test, as I noted about G4BUE earlier. He read the story of the OZ4LP-WB2OZW tests in the August, 1976 **CQ** with interest, but didn't get into very low

power work until W9PNE's story motivated him. At first, success with 500mw DX work led him to the 150mw input level with results that suggested that even much lower powers would be successful. Using the Argonaut with the standard 12v supply, the lowest possible input was at 150mw, but substitution of battery supplies down to 1.5v allowed him to reduce input to about 10mw. The interesting part of G4BUE's story is partially due to the antiquated practice of the G-QRP-C of measuring power in terms of input power, rather than output power as the rest of the world does it. His accomplishments, when measured in terms of input power were outstanding enough — but the real accomplishment could only be discerned when his output power was used as the standard. In his tests, G4BUE worked VE2FU and VE3IXE respectively on 21-and 28 MHz on March 3, 1979 while running 15mw input. During the ARRL C.W. DX Contest on March 18, 1979, he bettered his earlier successes by working W3MM, K8NZ, and K1ZZ on 28 MHz with an input of 10mw. Then the drama began to unfold. As Chris wrote about it: "I was over the moon in having worked across the Atlantic, three times, with an input power of 10mw. I felt this had bettered the WB2OZW transmissions. But then came the crunch!" Having read my article on r.f. output as a standard of comparison, Chris became curious as to his actual r.f. output power during the three record contacts, wondering just how his records compared with WB2OZW's. Unaware of the very low efficiency of the Argonaut with reduced drive, Chris had an engineer friend make measurements of the Argonaut's actual output power at the government laboratory using a \$60,000 oscilloscope and other instrumentation. At the 10mw input level used to establish his records, G4BUE's Argonaut was generating exactly 576 microwatts! This amounts to just a bit more than one-half milliwatt! The previous accomplishment, as measured in terms of 10mw input power, took on an entirely new magnitude!

And indeed, G4BUE's work does represent a phenomenal achievement either way, but the true accomplishment can only be seen when the output power standard is applied. As Chris noted in a letter, he was ecstatic at working across the pond with 10mw, but the output power discovery led to incredulity: "I could not see how it was possible to work across the Atlantic on microwatts . . . Is this the first time someone has worked across the Atlantic on microwatts? I wonder if you have heard of anyone else doing anything similar with similar power levels?" Discovering the low efficiency of the Argonaut at reduced drive levels had further implications for his quest for DXCC-Milliwatt — he had been operating at one watt input, although the award standard is output power. The countries that he had worked to the time of output power measurements numbered about 70, and he had worked them with 144 milliwatts r.f. output! His DXCC-Milliwatt Trophy #3, in effect, represented an achievement with an 8.4dB handicap in comparison to the other DXCC-Milliwatt qualifiers! Needless to say, G4BUE's installation efficiency and operator skills are outstanding. More recently, other QRP'rs have racked up million-plus miles per watt records, including Dan Lewis (N6HY), and John Pearson (KF4JU) on 1296 MHz of all places!

In short, QRP operation is applicable to almost every interest area in the amateur radio hobby, regardless of whether the individual is interested merely in casual rag-chewing or testing his skill against Nature's ultimate limits. There is a unique philosophy underlying QRP operation that translates human curiosity about Nature into an exploration of her laws and limits at the power threshold where operator knowledge and skills become the deciding factors. Whatever his interest, the QRP operator is always trying to discover and learn more about radio. Plato was one of the first philosophers to point out that the drive to learn is innate in human nature and provides the noblest form of fulfillment and personal satisfaction. QRP does just that!

VI. For the Novice Operator

Novice QRP operation is a special case, since just about everyone on the Novice bands is a beginner, and as a result the Novice QRP'r cannot expect skilled veteran operators on the other end to pick his weak signal out of the QRM. In fact, operating on the Novice band can be downright frustrating at any power level, let alone at QRP levels. Every so often I slip up into one of the Novice bands and have a go at it. I am often baffled by the fact that I am doing everything right and still get no responses. The Novice has to be realistic about his expectations: as a general rule, Novice band operation produces a much lower calls/contacts ratio than operating in other segments. The QRP Novice can expect an even lower ratio. However, this should not discourage beginners who like the QRP approach from attempting Novice QRP operation. If approached with the correct attitude, the time spent on the Novice bands can be an extremely valuable learning experience. That's what the Novice license is about in the first place! Compare to other band segments, the Novice bands are where the real "test of fire" and "sink or swim" challenges exist, and an individual who perseveres there already has developed the virtue of patience so necessary to successful low power operation. If the new Novice commits himself to learning about how all the critical factors come together in producing successful operation, he can survive and thrive on the Novice bands, even while using low power. Moreso than with most other types of operators, the successful Novice QRP operator knows he's done his homework and learned his lessons — otherwise he wouldn't be making any contacts! A little story will fit in well at this point and clarify the matter better than anything I could say.

Back when **The Milliwatt** started up in 1970, I began receiving letters from a new Novice in Iowa City, IA, who was experiencing a great deal of frustration with QRP operation on 40 meters. By the time he got around to writing "QRPp on the Novice Bands" (October, 1970) for **The Milliwatt**, Jerry L. Bartachek (WN0BEK) had taken his licks, kept trying and learning, and had come up a winner. Looking back over his six months on the Novice bands with about one watt output, he noted about his beginning: "Because of antenna space problems, 40 meters was the first band I tried with QRP. Using a random wire antenna, I contacted 5 or 6 states. And believe me, it took a lot of work to accomplish even that! There were multitudes of unanswered calls." Jerry suspected that his simple antenna had to be the source of his frustration, so he solved that problem: "After a while, I decided to build a new antenna to see if I could improve my poor record of states worked. An inverted Vee was the answer, again because of space limitations. Now I have a nice Vee up about 20 ft. at the apex. It's not a super-antenna by any means, but it got me 17 states to date on 40 and 80 meters. That's right, 80 meters! I feed the coax with inner conductor and shield shorted together, treating it as a random wire and matching by means of my handy L-network. This antenna appears to be efficient on 80, probably because the Vee top acts as a large capacity hat to supply top-loading for the coax feedline. Whatever the theory, it works!" The theory came from reading. And the antenna made the difference for Jerry: "Using this antenna on 80, one night I worked Oklahoma, Tennessee and Michigan, all new states, all worked consecutively with no unanswered calls in between, and all in one hour and twenty minutes. It took so long because I had to chew the rag with each of them!" We'll excuse the bragging because that's quite natural for a QRP'r who's solved his problem and is getting out!

Beyond that, Jerry analyzed the 40 meter situation and arranged his operating habits and techniques to suit that Novice band: "My standard practice is to rarely call 'CQ', but usually to answer other stations." After being ground-up countless times in early evening QRM, Jerry figured out what to do about it: "I also observed that the 40 meter Novice band is most crowded during 'prime time', from 1900-

2200 local time . . . so I've operated after 2200 or before going to work in the morning, and I find I'm making more contacts than possible during prime time." Notice that his strategy is the same as that advised nearly a half-century earlier in one of the low power reports in **QST**. He also realigned his expectations to more realistic levels: "Boy do I like 80 meters! It's more sparsely populated than 40 meters is, and besides there is no problem with foreign broadcast station QRM. As a matter of fact, I find that 80 meters isn't really dead in the daytime, merely uninhabited. So, if you want to talk to someone locally for a while, use 80 meters. The local guys are just as brilliant at conversation as those 700 miles away, and you probably have a lot more in common with the locals." As a result, his Novice QRP career ended with a sense of satisfaction and accomplishment as he prepared to move down into the General segments after passing his Advanced exam.

There is a lesson to be learned from WN0BEK's experience. Obviously, if something isn't working, the operator has to research the area and figure out what is wrong. This goes for antenna and propagation theory, circuit theory, and operating approaches as well. One thing that Jerry could have noted was the importance of reading in his success. One cardinal rule that the new Novice should follow will seem unpalatable, but unless the rule is followed, the Novice will never end up with WN0BEK's sense of accomplishment. And that rule is: the Novice must study about radio and what makes it work. He won't get anywhere unless he spends three hours of study for every hour of operating. He has to read and re-read until it makes sense and begins to explain the phenomena he encounters while operating. I know that amateur radio is supposed to be fun, and it is, but the catch is that it doesn't become fun until the hard work of learning prepares the Novice to be a successful operator. The new Novice or prospective Novice who has read this chapter and found many unfamiliar principles or practical factors that puzzle him need not be discouraged. In fact, he should be encouraged because the chapter contains a lot of material that will have to be learned sooner or later if any success as an operator is to be attained. Go back and re-read it and check items that are unfamiliar — that's the first "reading list"! Get a copy of the **ARRL Handbook** (1980 or later) and begin studying up on the checked items. A bit at a time will do. It'll take a while, but eventually, pieces will begin to fit together and will be useful in operating a Novice QRP station. Otherwise, the Novice grows up to be another appliance operator who needs a KW!

To conclude, if there is one thing that is the key to success — and I'll say it again and again even though good books are supposed to avoid repetition — it is the antenna system. So, pick it carefully to exploit your financial and space situations to the maximum, cut it carefully according to the dimensions given by handbook tables or formulae, spend the extra 15 cents-per-foot for quality 97% shield braid RG8/U coax, take the time to correctly solder the coax to the antenna and weather-proof the joints, and finally, make the effort to get it up as high and in the clear as possible. Cut corners and do slipshod work and you'll be beating your head against a brick wall. But do it right in the beginning, and then you can concentrate on learning the other things that are important in successful operation, knowing that your antenna is the best you can put up. With a choice of 80, 40, 15, and 10 meters, the Novice has a great deal of flexibility with respect to band choice, and the general hints given earlier can be applied accordingly, but with a minor qualification. Don't expect to realize the same kind of results noted earlier for the General bands or the same degree of consistency. The hidden variable is the quality of operator that happens to be on the other end. A transcontinental contact on the 40 meter Novice band is an event of sorts, but if you have that efficient antenna up 50 ft. and are pumping 3 watts into it, you know that it can be done if the right operator shows up! The only thing to do is to keep on trying until you find the guys who can copy a weak signal, until your studies lead you to feel

that you know what's going on, until that confidence in your ability to make contacts begins to build. From then on, QRP operating will begin to be all the fun that we QRP operators say it is. Just don't give up!

Chapter 2

Sharing the Joys of QRP

Just fifteen years ago, QRP operators were rather lonesome, isolated individuals, pursuing their unique approach to the hobby on their own, except for an occasional contact with another QRP operator. Such chance contacts were the only opportunity that a QRP operator had of learning that there were others like himself out there and exchanging information about QRP experiences, operating hints and the like. The QRP-ARCI was in existence at that time but defined QRP as 100 watts. Those of us who met via the QRP-ARCI wanted to distinguish our brand of low power from the club's standard, so we added a little "p" and called our interest "QRPP". It was in reaction to the QRP-ARCI's 100 watt QRP emphasis that I came up with the idea of starting **The Milliwatt: National Journal of QRPP**.

Mike Czuhajewski (WA8MCQ) had edited the QRP-ARCI/9 newsletter on occasion, and included a section entitled "QRPP Corner" to give some space to the low power members. We tossed the idea of **The Milliwatt** around for a while, during which time Wes Mattox (K6EIL/2) offered his skills, and finally, we decided to go ahead with it and see what happened. It's funny how an idea grows. At first, we contemplated the same kind of mimeograph newsletter format that other clubs used. But then I asked, "why not do offset printing in magazine format? No reason. Do it!" Then came the problem of the name for the journal. By this time, others had heard of the idea and added their two-bits. Suggested names included such inspirations as "The Pennywhistle," "The Softenboomer," and "The Virus" among others. The name was narrowed down finally to a version of the final one, and **The Milliwatt** remained after I typed out "The Milliwatter" at the head of the first page of the first issue, and then blotted out the "er" to see how it would look, and then added "National Journal of QRPP" as a final touch. A touch of class! And to make absolutely clear what the slant of the magazine was, I added the subtitle line: ". . . devoted to under five-watt amateur radio." At that time, if anyone had suggested that **The Milliwatt: National Journal of QRPP** would have an international impact and turn thousands of amateurs to the QRP route, I would not have believed it. But that is just what it did! By the time publication ceased in June, 1975, after a run of 31 16-page and two 32-page issues, it had attracted subscribers and contributors from all states and over 40 countries! It spawned QRP clubs and activity around the globe. It made the amateur radio world here in the U.S. once again aware of the principles that had been lost sight of in 1927 or so. **The Milliwatt** provided the fertile ground in which the ideals of Kruse, Hatry and other early pioneers could take root, flourish, and spread throughout the world.

Today, the QRP operator need not work alone, unaware of what others are doing and have done. The opening "Editorial Lucubrations" of the first issue spelled out the situation as it existed in 1970:

"As you probably realize, despite the large number of hams interested in QRPP, none of the major ham mags — or the national newsletter of the QRP-ARC-I, for that matter — has provided the QRPP'r with an opportunity to exchange ideas and technical information, and, as a result, most of us have been ignorant of the overall picture of QRPP activity and technical progress. This has been good, in a sense, because QRPP'rs have been forced to design their own rigs and have thus

advanced the state of ham radio, especially with respect to emergency and fixed operation from independent power sources. But, on the other hand, most newcomers (and some oldtimers) are in the dark as to what to expect from QRPP, and, in fact, every aspect of the subject. The Milliwatt will provide hams with the forum for the exchange of such vital information. We hope that The Milliwatt will lead many interested but uncertain hams into the fold of the 'already present and ever-growing lunatic fringe of flea-power amateurs' by providing operating info and construction projects." We thought that our number was large back then because we knew of, say, ten other guys who were operating QRP! Today, we know what "large" is — QRP is the "new wave" in amateur radio, and in a sense, **The Milliwatt** started it all!

Yet it would be inaccurate to attribute the success of **The Milliwatt** to any one individual — it was an idea whose time had arrived, and it attracted many dedicated contributors whose calls and names were already familiar, and then some who would become familiar later. C.F. Rockey (W9SCH) joined the staff in the second year of publication and wrote voluminously for the journal in his common-sense basics-of-radio approach. Many other veteran QRP operators arose to my invitation to share their expertise with newcomers to QRP, and they are the one who made the idea blossom. By the third year of publication, more high quality material was being contributed than could be published in the 16-page format, and as a result, **The Milliwatt** attained a level of excellence that it is remembered for today. That excellence grew out of the fact that the many operators who contributed to it were dedicated idealists who wanted to make the world of amateur radio a better world. **The Milliwatt** in effect was a success to be credited to the grass-roots low power operators — they obtained a QRP forum, and they made certain that it would be a valuable one.

When **The Milliwatt** ceased publication in June, 1975, it was at its peak, with promise of becoming even better. The files were left with a stack of top-quality material 3 inches deep, and a subscriber list of about 800 QRP operators from around the world. In a sense, its very success was its undoing. Even though I had the operation of the magazine down to a fine-honed system, the paperwork involved was simply staggering. To complicate matters, a divorce disrupted my personal situation, and I contracted a viral infection that kept me on the pneumonia borderline for seven months of 1975-76. The health problem made it totally impossible to continue, and once that cleared up, to put the journal back into operation would have been a mind-boggling effort. By this time, **CQ** had been carrying my QRP column for over a year, and I decided to let **The Milliwatt** die. My hope was that the QRP forum that **CQ** provided would serve to keep the awareness of QRP alive; but more than that, I had hoped that the movement toward QRP that **The Milliwatt** started would, after missing a heartbeat or two from its death, begin beating with a new life of its own, would live on its own. It did.

I. QRP Organizations

QRP is bigger now than we ever dreamed it could be. The QRP operator is no longer a lonesome individual plying his unique trade alone on high power bands. QRP organizations have sprung up around the world providing the QRP operator with a framework in which to operate, to communicate with others like himself, to exchange hints and information, to exchange circuits and technical advice, to work for QRP awards, and to engage in QRP operating activities. The QRP clubs have prospered so much that back in 1980, the need became apparent for a coordinating organization. Thom Davis (K8IF), then-president of the QRP-ARCI, expended considerable time, energy and money in creating interest in such an organization, and the result is the World QRP Federation. The WQF provides an integrating force for a world-wide QRP movement and benefits amateur radio as

no other organization can. It is needed. QRP has become so common an approach in the amateur radio world that it is difficult to tune across any of our bands for ten minutes without encountering a QRP station. For those who wish also to belong to a QRP organization and exchange information via the club's newsletter, the following list will provide a selection for your location. At this writing, the clubs have agreed, under the auspices of the WQF, to a definition of QRP operation as **LESS THAN FIVE WATTS OUTPUT/LESS THAN 10 WATTS INPUT.**

(1) **QRP-ARCI.** The QRP Amateur Radio Club International has done much for the past 20 years to popularize the idea that high power is not necessary to maintain effective communications. However, during much of that period, the QRP-ARCI defined QRP as 100 watts input, a classification as extinct as the dinosaur. BUT, and the big news on the QRP scene for 1980, the untiring efforts then-President Thom Davis (K8IF) led to a surprising reversal of the club's long-held stance. While it seemed quite clear from QSO Party entries and the club roster that the majority of members were 5-watt types, the old-guard power structure had steadfastly refused to budge a single watt below the 100 level in the club definition of QRP. All that changed, and the QRP-ARCI has become a vital, credible influence upon QRP efforts around the world. Through a series of two membership polls, followed by a ballot, club members voted by a wide margin to adopt the **OUTPUT POWER** standard and the 5-watt limit as the official definition of QRP. The results shook up the Board of Directors sufficiently to motivate a closed vote on changing the club into a genuine **UNDER FIVE-WATT OUTPUT** organization. Since then, the QRP-ARCI awards program has been implemented upon the basis of that standard. The club program includes several awards for QRP operators, the assignment of a lifetime QRP number to be used in club activities, a quarterly newsletter that has reached new heights of excellence under the editorships first of William Dickerson (WA2JOC), then Peter Spotts (N1ABS), Terry M. Gregg (KA5EXI), and now Fred Bonavita (W5QJM). The club sponsors several on-the-air operating events each year and several QRP NETS. The dues for joining are currently \$6.00 (U.S.), \$7.00 (DX) and cover the cost of the quarterly newsletter **QRP Quarterly**. Payment by check or money-order to: Wm. K. Harding (K4AHK), 10923 Carters Oak Way, Burke, VA 22015.

(2) **MI-QRPC.** The Michigan QRP Club was founded in January of 1978 and is a genuine under five-watt output organization whose purpose is to promote QRP operation world-wide. Club emphasis is upon members' attempts to improve their skills through schedules, NET operation and contests, and the club has grown considerably. The Michigan-based group emphasizes personal interaction of members through monthly club meetings at the homes of various members, and this active sense of fellowship has attracted a large number of Michigan amateurs to QRP. The club encourages the formation of chapters wherever five or more QRP operators reside within convenient distance of each other. The local-chapter concept was conceived by Ralph Burch (W8LCU), longtime QRP advocate, and founder of the club. The concept is an excellent one, since personal meetings provide the maximum opportunity for sharing of expertise and knowledge. The club offers a bi-monthly newsletter "The Five-Watter" for members covered by the initial membership fee of \$5.00, which also includes a beautiful, tri-color shoulder-patch with the club's logo, and an opportunity to purchase QSL cards using the club's design. The club offers awards and sponsors a QRP NET which is coordinated with the QRP-ARCI NETs. For membership information, contact Ralph Burch (W8LCU), 281 Crescent Drive, Portland, MI 48875.

(3) **G-QRP-C.** The G-QRP-Club was founded back in the fall of 1974 by Rev. George Dobbs (G3RJV) to foster QRP operation in England. The club "took off" just like **The Milliwatt** did five years earlier, beginning with about 30 members, increasing to 250 by the end of 1976, thence to 500 in spring of 1978, enrolled the 1000th member in December, 1980, passed 1500 by the end of 1982, and is cur-

rently mailing to nearly 3000 amateurs! These numbers provide an indication of the dramatic growth of QRP that we've seen in past years. Members are spread out across the world in more than 30 countries. Unfortunately, the G-QRP-C defines QRP as under-five-watts INPUT despite the fact that everyone else uses the double standard (10 input, 5 output) and as a result, the most thriving QRP influence in the world is basically ignoring the cogency of the output standard and muddling the prospect of world-wide unity on the standard. For the most part, the club leadership is aware of the importance of using the output standard and many members rely on their wattmeters, but no change is in sight. British traditions (even those only 8 years old) seem quite difficult to shake loose. Hopefully, the club will experience the same type of force internally that changed the QRP-ARCI's definition to the output standard. Time will tell! The worst thing to do is suggest that the club change its standards to catch up with the modern world. Tradition, you know. Even so, the club offers an excellent selection of QRP awards, assigns a member QRP number, and promotes several on-the-air NETs as well as contests. The outstanding feature of the club program is the quarterly newsletter/journal **SPRAT**, usually 20 pages in length, carrying not only club news, but technical and construction articles on QRP subjects, up-to-date information about world-wide QRP activities, and comments from members. **SPRAT: The Journal of the G-QRP-Club** is an echo of **The Milliwatt** in regard to format and content and continues to develop toward **The Milliwatt's** level of excellence. The club is worth joining just for **SPRAT**. Membership/subscription fee is 3.50 Sterling (U.K.), \$9.00 (U.S.); send money-order or check in local currency, no IRC's to: Alan Lake (G4DVW), 7 Middleton Close, Nuthall, Nottingham, NG16 1BX, England.

(4) **CW-QRPC-VK**. The CW Operators QRP Club of Australia has recently gotten underway after the demise of the VK-CW-QRP Club which was founded by Jack Swiney (VK6JS) back in 1980 to promote QRP activity in Australia. After three years of growth, the club ceased activities. Fortunately, the momentum it generated among Australian QRP'rs has led to the formation of the new CW-QRPC-VK. Membership is open to QRP'rs everywhere and a quarterly newsletter "Lo-Key" is included. The first issue featured two construction projects in addition to news. Club definition of QRP is 5 watts output, and also includes a 2-watt "QRPp" class and an under-one watt milliwatt class. The club sponsors the "VK vs. the World" QRP contest in November and sponsors a QRP activity NET Friday evenings at 0930Z on 3530 KHz, followed by a club information NET at 1030Z on 3575 KHz. The club's QRP calling frequencies are different from the world-wide set: 3530, 7025, 14050, 21130 and 28125 KHz. Membership fee is \$4.00 local, \$10.00 foreign, to: Len O'Donnell (VK5ZF), 33 Lucas Street, Richmond 5033, S.A., Australia. This is great news from "down under," since the loss of the VK-CW-QRP-C was lamented in QRP circles around the world. Good luck to this new organization!

(5) **Benelux QRP Club**. The Benelux QRP Club was founded by Franz Priem (PA0GG) back in about 1975 to promote QRP activity in Holland. The club emphasizes activity, both in regard to members interested merely in SWL'ing as well as transmitting amateurs. The club espouses the 10 input/5 output standard. The newsletter "Nieuwsbrief" includes technical articles, operating information and construction articles. Since it is published in the local language, it will be of little interest to anyone outside of Holland. Local operators contact: Frans Prien (PA0GG), Ir. Lelylaan 69, Heemstede, Netherlands.

(6) **GRUPO-QRP do Brasil**. The GRUPO-QRP was initiated in January, 1978 by PY1TU (Paulo), PY1LG (Lev) and PY1MHQ (Rhony) to promote QRP activity in Brazil. The club has adopted the 10 input/5 output standard. Membership is open to Brazilian amateurs upon submission of a QSL card bearing information about the operator's QRP transmitter specifications: upon acceptance, he receives a

membership certificate. The club encourages the home construction of transmitting gear. Brazilian amateurs should contact: GRUPO-QRP do Brasil, PO Box 700, 28600 Nove Friburgo, Rio de Janeiro, Brasil.

(7) AGCW-DL. The AGCW-DL group has been in existence for over a decade as an offshoot of the German national amateur radio organization. The emphasis of the group has been to promote c.w. activity at low power levels, and QRP is defined according to the 10 input/5 output standard. The AGCW-DL has sponsored a twice-annual contest in winter and summer for the past ten years or so. DL amateurs can contact: Siegfried Hari (DK9FN), Spearstrasse 80, D-6453 Selignestadt, Fed. Republic of Germany.

(8) ZS-ALGOA QRP Group. The Algoa branch of the South African Radio League shows 60% or more of the membership as active in QRP, and has formed a QRP sub-group. The objectives: "encourage QRP operation and generally result in more proficient operators and more efficient stations, and to show what can be done with low power." Sponsors a club construction project and a local award for working all 27 branches. Contact: Waldie M. Bartie (ZS2WM), Algoa Branch, S.A. Radio League, PO Box 10050, Linton Grange, Port Elizabeth 6015, S.A.

(9) JARL-QRP Club. The JARL-QRP Club was formed as a sub-group of the JARL and promotes QRP activity in Japan. Locals contact: Takahisa Masuzawa (JH1HTK), 1-8-15 Oogigaya, Kamakura, Kanagawa 248, JAPAN.

(10) EA8 QRP-DX Club. The club produces a newsletter entitled "QRPp Boletin Informativo" and promotes local activity. Contact: Agapito Montero Martin (EA8EY — DXCC-Milliwatt #6), c/ Molinos de Viento 2-20, Santa Cruz de La Palma, Canary Islands, SPAIN.

(11) QRP Club ARI. The Italian QRP group operating in the context of the national organization and sponsors a yearly contest. Contact: Sandro Santucci (I0SKK), Via Simon Boccanegra 8, Roma 00162, ITALY.

(12) QRP Klub YU3EOP. YU operators can contact: Rado Krizanec (YU3UQR), Bezenskova 1, 63000 Celje, YUGOSLAVIA.

A QRP group is also active in Norway — the Scandinavia Activity Group — with QRP emphasis. Information about these groups appears periodically in the **QRP Quarterly** and **SPRAT**.

II. QRP Awards

Quite a few awards are offered to the QRP operator for various types of achievements. There is a certain degree of duplication, since the individual clubs have been oriented toward amateurs in their own locations. There are two classes of awards: (1) those offered to all applicants, and (2) awards for club members only. The following list reproduces official information available at this time. Refer to the addresses for clubs listed earlier when requesting information about applying for awards. It will be appropriate to begin the list with the ultimate QRP awards for DX work.

(1) DXCC-Milliwatt Trophy. Initiated by **The Milliwatt** in 1971 and offered in its memory. Perhaps the most difficult award now offered to radio amateurs. To qualify, an operator must submit QSL proof of two-way contacts with stations in 100 ARRL DX countries while not exceeding one (1) watt r.f. output from his transmitter. All qualifying contacts must be initiated, maintained, and completed at this power level. Special conditions apply with respect to contacts worked via NET or "list" situations. The DX station must locate, recognize the call of, and communicate directly with, the QRP station without assistance from the NCS or "list control station," other than the latter informing the DX station that a QRP station is next in line to make a call. The NCS cannot relay the actual call of the QRP station; if he does, the contact is invalidated at that point as far as the award is concerned.

Applications must include the following: (1) a log list of the 100 contacts alphabetized by prefix (i.e., A2, DL1, G . . . PY . . . ZS . . . 4X4 . . . 9Y5), including the pertinent information such as date, time, station worked, band, mode and r.f. output for each contact; (2) one QSL verification for each listed contact; (3) a description of the method used to measure r.f. output power, and the measurements made — in the event that an un-modified commercial transceiver is used, and that unit is known to be unable to exceed the specified output power limit, the unit will serve as de facto proof of the power limit; (4) a signed affidavit attesting to the veracity of the applicant's claim that all contacts were initiated and completed with the given power limit according to the above conditions regarding power limit; (5) a \$24.00 U.S. fee to offset part of the cost of the handsome 28 inch trophy given as the award (any additional contribution is greatly appreciated!). Foreign applicants should attempt to submit U.S. dollars unless impossible. It is suggested that the applications/QSL's be sent via certified mail — 88 mail transactions involving QSL's have been successful with no loss of extremely valuable cards yet. **For applicants in Europe, Africa, and Western Asia, applications may be sent direct to the U.S. or to the Official Milliwatt DX Awards Program DX Representative, A.D. Taylor (G8PG), 37 Pickerill Road, Greasby, Merseyside, L49 3ND, ENGLAND.** Mr. Taylor will examine the QSL cards and the list of qualifying contacts, and will certify that the application is valid, and return the material to the applicant. The applicant then sends the list validated by Mr. Taylor (but not the QSL's) and the remainder of the items listed above to: Adrian Weiss (W0RSP), 833 Duke St #83, Vermillion, SD 57069 U.S.A.

(2) DXCC-QRPp Trophy. Awarded for working 100 ARRL DXCC list countries with an r.f. output from the transmitter not exceeding five (5) watts. The rules detailed for the DXCC-Milliwatt award apply to this award also, except for the power limit.

(3) DXCC-200-QRPp, DXCC-200-Milliwatt. Awarded to any QRP operator who submits QSL proof of two-way contacts with 200 ARRL DX countries. The rules are the same detailed above for DXCC-Milliwatt. The list of the qualifying contacts for the 100 countries level is kept on record, and an applicant for the 200 countries award need only submit a log list and QSL verifications for countries 101-200 if he/she has been awarded the 100 countries. A handsome suitably engraved plaque constitutes the 200 countries award.

(4) KM/W Award. The "thousand miles per watt" award is offered by the QRP-ARCI to any amateur transmitting from, or receiving the transmission of, a low power station such that the great circle distance between the two, divided by the output power of the transmitting station, equals or exceeds a ratio of 1000 miles per watt. For example, the transmitting station is putting out 0.75 watts, and the distance is 1250 miles: $1250/0.75 = 1666$, or 1.666 thousand miles per watt. Apply to QRP-ARCI with complete log data on the contact, including power output and distance, to: Leo Delaney (KC5EV), 22527 Millgate, Spring, TX 77373. Note that BOTH RECEIVING AND TRANSMITTING operators qualify for the award. \$2.00 fee.

(5) WAS-QRP. Worked All States QRP awards are offered by both the QRP-ARCI and MI-QRPC. Application to MI-QRPC should include the log list showing the 50 contacts, with an affidavit signed by two licensed amateurs that the applicant has in his possession a QSL verifying each contact. All contacts initiated and completed while not exceeding 5 watts r.f. output. \$1.00 fee. The QRP-ARCI WAS-QRP award is offered for confirmed contacts with 20 states for the initial certificate, and then sticker endorsements are given for the 30, 40 and 50 states levels. Special endorsements include (a) two-way QRP (all 50 stations worked were also QRP) and (b) all 50 states worked with less than one (1) watt r.f. output. Application includes log listing of qualifying contacts, QSL's, affidavit about power levels. \$2.00 to KC5EV (see #4).

(6) WAC-QRP. Worked All Continents QRP awards are offered by the QRP-ARCI, G-QRP-C, and IARU (International Amateur Radio Union), and the ARRL provides a QRP endorsement for its WAC award. Applications to the QRP clubs include the usual log listing/QSL's/affidavit and \$2.00 fee. QRP-ARCI to KC5EV; G-QRP-C to G8PG (see #1 above). The IARU award was initiated by Karl Smith (W0BWJ) and is effective for contacts from January 1, 1985. Application via ARRL. The ARRL requires that the six QSL's submitted indicate the DX operator's opinion that the applicant was operating at the QRP power level. This is supposed to prove something, but no one — except the ARRL — can figure out just what it proves! To ARRL Awards Dept., ARRL, 225 Main St., Newington, CT 06111.

(7) QRP-CW-250 Award. Offered by the AGCW-DL, the awards recognizes that an applicant has made 250 c.w. contacts on any band 160-10 meters during one calendar (January 1 — December 31) while not exceeding 10 watts input/5 watts output. Application should be accompanied by a log list showing the breakdown of claimed c.w. QSO's by month, along with a declaration by the operator: "I hereby certify that all the QSO's contained in this claim have been made using a transmitter input of less than 10 watts," and an additional two signatures by licensed amateurs verifying the claim. Fee of \$2.00 (or IRC's) to: Otto Weisner (DJ5QK), Freudendheimer Str. 14., D-6900 Heidelberg 1, Fed. German Republic.

(8) Milliwatt Field Day Trophy, One-Watt Field Day Trophy, QRP Field Day Club Plaque. The Milliwatt FD Trophy was initiated back in 1970 by The Milliwatt to encourage QRP operators to go out into the field and participate in the ARRL FD event, and to provide them with a special form of recognition in the QRP world in addition to the results published in **QST**. With the tremendous increase in QRP activity, the two American QRP organizations, the QRP-ARCI and MI-QRPC; have added their support to the program by sponsoring two new categories and an expanded awards offering. Participants in the ARRL FD can now compete in three categories: (A) Milliwatt FD Trophy, for the two operator/one transmitter, under five watts output class; (B) the One-Watt FD Trophy, two operator/one transmitter, under one watt output class; (C) the QRP FD Club Plaque, for groups exceeding the two operator/one transmitter class — a club may operate either at the under-five watt or under-one watt output level if the one-watt multiplier is desired. In addition to the One-Watt FD Trophy, the new "Milliwatt Achievement Certificate" will be awarded in that category to 2nd-3rd place under-one watt stations, provided a minimum of 10 entries are received in the under-one watt class. **SCORING:** QSO's x Power Multiplier (5 watts -X4, 1 watt -X8) x X1.5 Emergency Power Mult. (battery, solar, wind etc) + 150 Bonus for full portable away from home shack, a.c. mains, permanent antenna installations. **ENTRY:** duplicate (xerox etc) of entry to ARRL Field day or similar — summary sheet showing breakdown of QSO's by band and mode, power/s used, type of power source, whether full portable or not, checklist of stations by band or log copy. By August 31 to: Adrian Weiss W0RSP, 833 Duke St #83, Vermillion, SD 57069. **NOTE: ONLY FULL PORTABLE STATIONS ELIGIBLE FOR TOP AWARDS**, and a station may win a class only once every three years.

(9) Milliwatt Achievement Certificate. The Milliwatt and the QRP-ARCI have joined together to sponsor the Milliwatt Certificate to high scoring under-one watt r.f. output entries in Milliwatt FD and the Spring and Fall QRP-ARCI QSO Parties. If a minimum of 10 entries are received, 1st-3rd high scores will receive certificates, otherwise only 1st place (QSO Parties).

In addition, the clubs offer awards for members only. Details about these are available in club publications. (1) QRP-ARCI offers a DXCC award in increments of 25 countries, the QRP-25 award for contacting members in increments of 25, and the QRP NET award for check-ins on QRP-ARCI sponsored NETs in increments of 25 check-ins. (2) The MI-QRPC offers a DXCC award in increments of 25 countries, a Worked Membership Award for contacts with members in increments

of 10, and a QNI Award for checkins on the club NET in increments of 25. (3) The G-QRP-C offers a QRP Countries Award for increments of 25 countries, a Two-Way QRP Countries Award for working QRP stations in DX countries in increments of 25, a Worked G-QRP-C Members award in increments of 25, and the G2NJ Trophy and Partridge Trophy for annual outstanding contributions to QRP. Finally, awards in the form of certificates and trophies (in the **CQ** DX contests) are given to high scoring entrants in various contests open to QRP operators. Check official announcements as noted below for this information.

III. QRP Contests/Activities

One of the most popular types of QRP activity is the "contest" in which the major objective of the participant is to contact as many other stations as possible in a given time period such as a weekend. Each contest or activity has its own peculiar set of rules for participation and scoring. Each offers its own format for reporting results and making awards to high scorers. Two sources of details about specific contests and activities are available to the QRP operator: (1) the sponsoring organization's newsletter (and other organizations' newsletters usually carry listings); and (2) **CQ**'s "Contest Calendar" section, which carries complete details on contests approximately two months in advance. Any QRP organization sponsoring a contest should submit an official announcement, including all rules and the format for entries, deadlines and awards, to: Frank Anzalone (W1WY), Contest Chairman — **CQ** magazine, 14 Sherwood Road, Stamford, CT 06905. Submit material at least four months in advance of the contest. Publicity is the key to the success or failure of a QRP event, and many non-QRP'rs are attracted to a contest via the announcements in **CQ**.

In the following "calendar" of QRP events, 1985 dates are shown, except where no date has been set — check for current information in the club newsletters for these which are items marked "*". This list is intended to provide the newcomer with an idea of the types and number of activities of interest to the QRP operator.

- (1) AGCW-DL Winter QRP Contest. January 19-20. C.w. only.
- (2) G. Marconi QRP Phone Contest. February 2-3. 10 watts p.e.p. Sponsored by QRPC-ARI, the Italian QRP organization.
- (3) ARRL C.W. DX Contest. February 16-17. Separate QRP section.
- (4) ARRL S.S.B. DX Contest. March 2-3. Separate QRP section.
- (5) G-QRP-C Spring C.W. Activity Weekend. March 16-17.
- (6) **CQ** WPX S.S.B. Contest. March 30-31. S.s.b. section of **CQ**'s "prefixes" DX contest with QRP section and trophy.
- (7) RSGB Low Power Contest. 3.5/7 MHz QRP contest. April 21.
- (8) QRP-ARCI Spring QSO Party. April 20-21. Certificates awarded.
- (9) G-QRP-C Late Spring S.S.B. Activity. May 4-5.
- (10) **CQ** WPX C.W. Contest. May 25-26. QRP section with trophy.
- (11) QRP-ARCI Hootowl Sprint. * May 30. 2000-2400 local time.
- (12) Milliwatt Field Day. June 22-23, during ARRL Field Day.
- (13) RSGB 3.5 MHz Field Day. July 21. QRP section.
- (14) AGCW-DL Summer QRP Contest. July 15-16.
- (15) ZS QRP Contest. July 28.
- (16) QRP-ARCI Novice Band Sprint. * August 3-4. Provide Novices an opportunity to work the rest of us for satisfaction/awards.
- (17) QRP-ARCI Summer Daze Sprint. * August 24-25. S.S.B.
- (18) G-QRP-C Late Summer QRP Activity Weekend. September 28-29.
- (19) Ohio QSO Party. * September 15-16. QRP Section.
- (20) QRP-ARCI Fall QSO Party. October 12-13.
- (21) RSGB 21 MHz Contest. October 20. QRP section.

- (22) **CQ WW S.S.B. DX Contest.** October 26-27. QRP section.
- (23) **VK vs. the World.** November 16-17.
- (24) **CQ WW C.W. DX Contest.** November 23-24. QRP section.
- (25) **TOPS C.W. 3.5 MHz Contest.** December 7-8. QRP section.
- (26) **G-QRP-C Annual QRP Winter Sports.** December 26-Jan. 1.
- (27) **QRP-ARCI First Sunday QSO Parties.** *Throughout the year, Sunday afternoons.

As noted, details for these events can be found in **QRP Quarterly**, **SPRAT**, **CQ**, and other club newsletters. A very new possibility for QRP activity — not yet finalized by the IARU — is TF3KB's motion that the IARU sponsor an annual "QRP Day" on June 17. The purpose of the event would be to encourage all radio amateurs to restrict their power to QRP levels on that day. Let's hope that the idea carries — it would be a great opportunity for everyone to test out the effectiveness of QRP and get some idea of what the bands would sound like without QRO signals around.

The above list is rather extensive, showing how much activity is available for the QRP operator for meeting other QRP'rs and up-grading operating skills. In the U.S., The QRP-ARCI fall and spring QSO parties, as well as the "sprints", provide the big opportunity for meeting other QRP'rs. Entries are consistently in excess of 100-120 with a lot of activity. U.S. operators should listen carefully for European QRP'rs during these events on the high bands (20-10 meters), since G-QRP-C types usually try to work across the pond. Similarly, U.S. QRP'rs frequently put some time into the contests sponsored by the European clubs. Inevitably, some transatlantic QRP contacts occur as a result. During the big DX contests, there is quite a bit of QRP activity, but it is usually immersed in the general high power bedlam. Evenso, there is still an opportunity for two-way QRP DX contacts. For example, during the 1980 **CQ WW DX Contest**, SM0GMG was able to convey his gratitude for receiving DXCC-QRPp Trophy #22 directly to me during our two-way QRP contact in the midst of the contest mess. This was a thrill in several respects — a two-way transatlantic QRP contact first off, then SM0GMG's verification that he'd received the trophy, and finally, his expression of pride about the trophy! Likewise, I hooked up with G4BUE for the first time in a big DX contest, but part of the thrill was dashed by the fact that he was QRO at the time. Similarly, I've worked local QRP'rs in the midst of big DX contests, and once I located W9PNE on 10 meters and followed him down the band as we worked about 6 stations in sequence. But often the thrill of a two-way QRP contact during a DX contest must await publication of the results, where the QRP operator discovers that he has, in fact, worked several of the DX QRP entries without realising that they were QRP at the time! In any event, putting in the time and effort required to successfully operate a big DX contest is worth it when a two-way QRP contact results. In Chapter 7, we'll discuss strategies for operating several of the very popular contests in the above list.

In addition to the contest format, several QRP organizations sponsor unscored QRP gatherings for the purpose of giving QRP operators and opportunity to make contacts. The G-QRP-C Activity Weekend is an example of this approach. The strategy underlying such an event is quite simple — set up a time and place, and the QRP operators will gather there, rather than hunting around the bands and working QRO stations. These events are, in a sense, more enjoyable than the contests because there is no pressure to work as many stations as possible. Hence, a contact can be more leisurely and some exchange of information is possible.

IV. QRP Nets, Calling Frequencies

In the U.S., QRP-ARCI and MI-QRPC sponsor NET activities which have recently been coordinated. These NETs are an excellent opportunity to meet other club operators and to make contacts that qualify for in-club awards. While the NET structure is rather formal, it is possible to "pull" another QRP operator off NET frequency for a chat, and then return to the NET. Schedules for these QRP NET's change seasonally, so the best approach is to check the schedules in the **QRP Quarterly** and "The Five-Watter" for details. When checking into the QRP NET, first familiarize yourself with techniques of NET operation by listening to how it's done. Basically, the NCS station will call "CQ QRP NET QNZ?" and record the calls of responding stations, and then recognize each station in turn. He will then instruct a specific station to transmit when his turn arrives. The recognized station then is free to call whatever other stations he wishes to contact. Do not interrupt the procedure, for NET efficiency depends upon orderly conduct of business. Once the NCS has recognised you and entered you on the list, you will eventually be given your chance to make calls. Wait and enjoy hearing other QRP signals, noting propagation effects etc. Quite a bit of activity has occurred on the 80 meter NET in the past three years, the 40 meter NET is growing, and QNI's on the 20 meter NET have been sporadic, but with hordes of QRP stations checking in. It is delightful to sit at the rig and hear 10-20 other QRP stations from various parts of the country at the same time! The current QRP-ARCI NET activity is the result of the efforts of past-President Thom Davis (K8IF) who persisted in managing the 80 meter NET from 1975 onward during years when check-ins were sometimes non-existent. The NET system originated under the direction of **The Milliwatt** back in about 1973. It was amazing as NCS here in South Dakota to be in contact with stations ranging from Washington and Oregon to Texas and Florida to Maine — all QRP on 80 meters! All those mini-signals spanning half a continent and more! We even had a KP4 check in once with QRP and work several of the guys. An added feature is that the QRP-ARCI offers a certificate to any QRP operator who faithfully checks in, in increments of 25 times. At times, there are as many as 20 QRP stations on frequency on the 80 meter NET. Give it a try! **QRP Nets**. Weekly Net sessions in effect, January, 1985:

NET	Freq.	NCS	Day	Time
Transcon	14060kHz	W5LXS	Sunday	2300UTC
Southwest	3560	WD6DMY	Monday	0400
Southeast	7030	K3TKS	Wednesday	0100
Gulf States	3560	W5QJM	Thursday	0200
Great Lakes	3560	K5VOL/9	Thursday	0200
Northeast	7040	W1FMR	Saturday	1300
Southwest	7030	W6RCP	Saturday	1600
Northwest	7040	N7DGZ	Saturday	1800

Calling Frequencies. In order to expedite contacts between QRP stations at all times, the QRP organizations around the world have designated specific frequencies on each band as a gathering point for QRP operators. These are: C.W.: 3560, 7030(Europe), 7040 (U.S.), 14060, 21060, 28060 KHz
S.S.B.: 3985, 7285, 14285, 21385, 28885 KHz

QRP operators are encouraged to use these frequencies as a regular part of their operating routine. One major flaw in the system is attributable to the general QRP axiom, "don't waste time calling CQ with QRP." This axiom definitely is true when operating on frequencies other than the above-noted QRP calling frequencies. However, the calling frequencies are places where every QRP operator should put in some time calling "CQ QRP". Otherwise, everyone sits at his receiver listening for such a calls, and no one ever makes it; hence the general observation that the frequencies are unused by QRP operators. I hardly ever fail to raise of

QRP station on the calling frequencies when I decide to invest 15 minutes in calling "CQ QRP". So, after turning on the rig, tune to the QRP calling frequency, and if no one is heard calling "CQ QRP", go ahead and call for about 10 minutes at least. If everyone does this, I am absolutely certain that the calling frequencies will become a beehive of activity — remember, there are other QRP operators listening whose major skill is copying weak signals. They will hear the "CQ QRP" and jump to answer. Try it!

Chapter 3

Planning for QRP Operation

The first and perhaps most important "operating technique" really has nothing to do with tactics to be used on the air, but rather, the thought and planning that should precede on the air operation. With QRP, it is necessary to carefully consider the combination of important factors that promote successful operation. While the QRO operator need not concern himself with such planning, oversights and miscalculations by a QRP operator can spell the difference between a rewarding experience and failure and frustration. And the frustration continues until the QRP operator analyses his approach and discovers what is wrong in the circumstances underlying his operating efforts. In this chapter, pre-operation planning will be considered with respect to the manner in which the following factors must be combined if successful operation is to result. These are:

- (1) Objectives of operation.
- (2) Times of operation.
- (3) Antenna Capabilities.
- (4) Location.
- (5) Band selection based upon propagation.

I. Objectives of Operation

Typically, the initial objective of the neophyte QRP'r is to start making contacts. Given a week or two of bumbling around on the wrong band at the wrong time with the wrong antenna, a few contacts will inevitably result, but at a great waste of time and effort and possibly at the risk of losing interest in QRP "because it just doesn't work." Once the newcomer has succeeded in making contacts of any kind with some consistency and begins to believe that it works, he will typically redefine his objective and start working toward some particular goal or mode of operation. The various types of QRP operation have been discussed earlier in Chapter 1 — rag-chewing, contesting, DX'ing, WAS-QRP, DXCC-QRPp, etc. At each step of the objective-defining process, planning is necessary because a specific objective serves to focus the remaining factors that must coalesce for successful operation.

Once an objective is selected, a quick preliminary analysis of the remaining factors in light of that objective will provide a reasonable estimate as to whether the objective is feasible, and if not, how much effort is required to make it feasible. For example, the QRP newcomer most frequently selects as his first objective some award such as WAS-QRP. Suppose that WD4QRP has been operating QRP for about a month with reasonable success and knows that QRP "gets out". Deciding to aim for WAS-QRP he first checks this objective against his antenna capability. Satisfied up until now with just making contacts with anyone, he's been using a 15 meter dipole at 25 ft. After assessing the coverage possibilities of this antenna's horizontal and vertical radiation patterns, he turns to estimating what it

can do in an effort at WAS-QRP, given 15 meter propagation characteristics. He finds that, except for periods of very high solar activity with solar flux levels above 160 or so, distances of less than 900km via F2 reflections are almost non-existent. During the current low portion of the sunspot cycle, then, prospects of working close-in states are bleak. However, other factors have to be considered before either giving up on 15 meter WAS or “going for it.” Suppose our newcomer has been closely reading the propagation columns in **CQ** or **ham radio**. He finds that there might be an exception. Sporadic-E (**Es**) openings occur frequently between May and July on 15-10 meters. Very short-skip is possible during such an opening, making it possible to work close-in states. As long as he realizes that he has to first learn to recognize the conditions that signal an **Es** opening, and then wait until next summer, the 15 meter WAS objective could be realistic. Geographical location makes a difference also. In the “small states” region east of the Mississippi, very short skip is an absolute “must” for WAS-QRP. Located in Kentucky, WD4QRP would have to rely on **Es**. However, if we were considering WD0QRP, located in Kansas, a 900km coverage would include portions of all neighboring states. They would be possible, but perhaps difficult on 15 meters. On the other hand, if WD4QRP wanted to get going on WAS-QRP right away and felt certain that he’ll be able to work close-in states, he’d be better off to improve his antenna system to make use of short-skip bands such as 80-40 meters. No situation is “perfect”, but it is unreasonable to proceed with an objective in a very difficult or nearly impossible situation. Frustration will be the main reward in such a case. Several other factors should be worked into the planning formula. Let’s consider them next.

II. Times of Operation

First, the time periods of proposed operation should “match-up” with the likely on-the-air times of areas which are to be worked in pursuing an objective. Once that match-up is found, the time periods must be considered in terms of expected propagation.

(1) Your Time — His Time. A QRP operator aiming at a particular objective must be available during the time period when the operators whom he must contact are likely to be operating. Available time periods for operating are usually controlled by such factors as job, family, and various commitments and responsibilities. Let’s examine this with a few examples. The most common commitment is the 8-5 Monday-Friday job schedule here in the U.S., so jobs usually need not be a major restriction for stateside objectives. (Similarly, European QRP operators follow a fairly common European pattern, and so on.) Even with the coast-to-coast time differential, adequate flexibility can be scheduled to permit being on the air when the other operator is. However, for DX work, the 8-5 schedule can be a serious obstacle, since DX work depends more critically upon optimum propagation conditions, and these usually exist for relatively short periods of time (up to 3-5 hours to a given area when conditions are at best), DX’ing during the week for an 8-5’r can be very frustrating.

(2) Family. While this paragraph has little to do with QRP operating, it should be noted that frustration can result from sources other than failing to make contacts. It is wise to avoid choosing an objective which requires an hour or two away from the family during weekday evenings. XYL’s have a different way of looking at this, even though you’ve explained that you “have to be on the air” because QRP is the biggest challenge you’ve had in years and you’re more excited about it than anything you’ve done in years. Right. So she’s not exciting. Right. The same logic applies to “totally free” weekends. When it comes to QRP, excited newcomers bent on WAS-QRP or some other objective sit around at work all week imagining the stuff they could be working if only they were on the rig. The natural tendency is

to view the weekend as two full days of free time to “check out the bands and work some new ones.” However, family commitments and chores still exist, and the XYL spends weekdays at home planning chores to be done when her full-time “hired-hand” is on the premises. So, the wise QRP’r should be aware of the potential danger of an explosion, and judiciously plan a “give and take” program. Take time out for QRP, but give high quality performance in other family commitments. Make a habit of giving something everytime you take off time for QRP’ing. Few XYL’s will feel shortchanged if you approach it with: “Say, hon, how’d you like to run out to Sears and shop around for washers after I check out the band for a while — you know, just price ‘em and check out the specs.” Or, “I think I’ll go out and mow that lawn to work up a good sweat and then relax at the rig for awhile.” Or whatever.

(3) Juggling Operating Periods. To continue with “your time — his time” considerations for local stateside work, weekdays essentially provide two areas of flexibility: before work and after work. For an eastern station, the time differential with the midwest and west coast forces an adjustment during evening hours to allow western stations 2-3-4 hour “lag” times for their daily schedule to “catch up”. An operator in Oregon will be finishing the evening meal around 2100-2200 eastern time as a rule, and to work him, the eastern operator will have to be on during that time period. This raises the question of band characteristics. With solar flux levels above 100 and the A-index less than 12 or so, 20 meters should be open to the west coast. Otherwise, 40 meters is the next best choice. However, during solar lows, 20 meters could be closed by that time. The Oregon operator’s evening QRP’ing corresponds to the “wee” hours on the east coast, but by 0100 eastern time, most of the foreign broadcast QRM is gone from 40 meters and propagation is likely to be prime for long distance work. Of course, for the eastern operator, this means missing some sleep, but then he won’t have to “wake up” early to flip on the rig and check around or call “CQ W7”. The opposite time relationship applies to the Oregon operator looking for Vermont and Rhode Island. Getting up 3 hours earlier than usual will usually provide 40 meter (80 as well) to the east coast. However, because of intense foreign b.c. QRM on 40 during east coast evening hours, the Oregon QRP operator has but a slim chance of making it. In short, given an 8 hour workday as universal, weekdays do provide some flexibility, but not much, especially with respect to daytime operation on 20-10 meters for working the distant states. 80 meter capability is a definite advantage for evening collections of close-in states.

(4) DX Times. Here, the propagation characteristics necessary for QRP DX’ing force a much tighter combination of factors. The area time differences involved can seriously limit possibilities of success. In contemplating DX operations, some research and charting is useful in attempting to visualize possible time match-ups with various areas of the world. Eastern U.S. operators obtain the majority of their DXCC QSL’s from the European area, while western U.S. applicants for DXCC-QRPp depend heavily upon Asia and Oceania for their QSL’s. Midwestern U.S. stations are in the middle and take a combination of both. Caribbean and South American contacts usually don’t involve much of a time differential, but the other areas do. Local lifestyles often show significantly different scheduling patterns when compared to the U.S., so at times, it helps to learn something about that subject. For example, Mediterranean lifestyles include a quite non-American siesta in the afternoon, providing a possible operating period not present in the American way of life. The American operator can match-up with that European break depending upon the actual time differential.

(5) DX Primary Path. At first, concentrate on examining a major path in assessing your DX possibilities with respect to time match-ups. The usual two criteria to be met are the “your time-his time” match-up and propagation probabilities. You may find that your available weekday periods simply do not coincide

with the “probably on” times at the DX end. For example, W0RSP is separated from Europe by a 5 hour time differential, European operators will probably be in bed by the time his 2100 local time period rolls around — over there, local time is 0200. However, assuming that any European operator who wishes to work DX operates before leaving for work at 0800, I can schedule a period at 0000-0200 my time. Next, a “pre-work his-time” period of 0600-0800 must be checked against propagation probabilities. The early half of the period places both ends of the path in darkness with attendant implications. At his end, **foF2** will have dropped to its diurnal minimum, while at my end, it will be about half-way toward the minimum. However, the entire path will be in darkness. Depending upon solar activity and season, 21-28 MHz will typically be closed except when the solar flux is above 115-125 with an A-index below 9 or so. With the flux level above 145 and similar A-index, 14 MHz can stay open for this path all night, and with D-E absorption absent, path loss is at a minimum. During flux levels above 165, Europeans have frequently been heard in South Dakota at S6-S8 levels during the wee hours, and the main problem in working them was local QRM on the European end from dense activity. Other time periods should be checked against propagation in a similar manner. Afternoon South Dakota periods correspond to evening European periods, and depending upon flux levels, 21 and 28 MHz provide dependable paths. Overall, DX'ing with QRP requires considerably more planning, especially if DXCC-QRPp is the objective. In that case, one major path is not enough — the QRP'r aspiring to DXCC-QRPp can begin working toward the award once he has examined the “easiest” path, but remaining paths to other areas of the world will have to be analyzed as well.

(6) Time Periods vs. Propagation Periods. In addition the various time cycles related to propagation have to be considered in planning “Times of Operation”, as implied in the above examples. Overall, the point in the 11 year sunspot cycle, the 27 day solar flux cycle, the daily flux level, and the time of day at reflection zones along the proposed path are factors to be considered. The point in the 11 year cycle is useful merely as a general index. However, since the daily solar flux levels vary in 27 day cycles, the trend of the flux across a week or two is adequate to show where conditions are heading. At times it is inconvenient to check WWV everyday for flux levels, but periodic checks separated by several days are a good indication of whether conditions are on the upswing or are dropping. For example, moving from mid-December to mid-January, 1983, flux levels varied from about 180 down to 118. Conditions varied accordingly, with 20 meters losing night openings as the flux moved downward through about 135. Several days after the 118 report, the next report showed the flux at 127, and the reversal is a clue that the 27 day rise is beginning and conditions will gradually improve during that period. So, the trend of the daily flux is the most practical index for the operator who can't be on every day. Daily variations in critical frequencies correlate closely with flux activity levels, but seasonal variations are superimposed upon the basic correlation and modify it. So, a flux level of 150 will have a specific set of connotations for night operations across the South Dakota-Europe path during July which may not correspond to November periods. The material in propagation columns and the **ARRL Handbook** is useful for assessing seasonal and diurnal variations for specific major paths, and **QST's** “How's DX” column includes **MUF** (Maximum Usable Frequency) graphs for those paths. Some general observations will be found below in “Band Selection”.

III. Antenna Capabilities: Notes for Novices

Obviously, the QRP operator's antenna must be capable of efficient operation on the bands that will be used. Beyond that basic requirement, an antenna exhibiting gain and directivity is a definite advantage in QRP operation, and where

finances permit, such an antenna should be the primary objective. Before discussing how the operational characteristics of antennas provide the major context of planning for QRP operation, a word to Novices is necessary.

(1) Novices and Antennas. Actually, while I've placed "Objectives" at the top of the planning list, it would have been just as valid to have placed "Antenna Capabilities" there, especially if the reader is both a newcomer to QRP and a Novice. The Novice typically believes that the greatest amount of thought and planning must be directed toward choosing the best rig for the money that is available. Frequently, Novices suffer considerable anxiety about this choice, and in checking over ads or querying "Elmers", end up even more anxious, frustrated and confused. I can understand this approach, since a new or used rig represents a considerable outlay of cash and can not be taken lightly. However, this is a classic case of misplaced priorities. The antenna should be the primary consideration! Having seen the ham shack photos in the magazines and visited a couple local shacks, the new Novice understandably associates successful hamming with top-notch gear. Would that every new Novice could see some of the junk equipment I've used in racking up DX scores and the like. In fact, about the only pieces of unscratched new gear I've ever owned were the 515 and HW-8 I tested and reviewed for **CQ** magazine. The point is: if it puts out r.f., it needs an effective antenna to produce contacts.

(2) Learn the Basics. The first step for the Novice is to familiarize himself with the basics of antenna theory. In terms of planning operations, this includes basic theory about the horizontal and vertical radiation patterns for various electrical heights above ground. The **ARRL Antennabook** is the standard source for basic theory and the graphs to be used in planning. Graphs usually are presented with dimensions given in units of electrical length such as "one-half wavelength", and these can be converted to actual dimensions by:

$$L(\text{meters}) = 300/\text{fMHz}$$

(or)

$$L(\text{ft.}) = 984/\text{fMHz},$$

the formulae for determining one wavelength at the frequency specified. In some discussions, dimensions are expressed in units of electrical degrees, as in "antenna height in degrees". Here, the number of degrees is divided by 360 to produce the decimal or fractional wavelength that applies. So, an antenna height of 90 degrees equals:

$$90/360 = 0.25 = 1/4 \text{ wavelength.}$$

Then the height in feet is:

$$L(\text{ft.}) = (984/\text{fMHz})/4.$$

Going the other way, a given dimension in feet must often be converted into wavelength (shown as "W" here) by:

$$W = \text{ft.}/(984/\text{fMHz}).$$

The Novice should practice thinking in terms of electrical length as a matter of course in order to gain some facility in moving back and forth between electrical and material units of length.

(3) Space. Quite frequently, available space is a key factor in determining antenna possibilities for a given situation, and hence band selection and objectives. Available space can limit flexibility and force decisions in planning operations. Suppose, for example, WD4QRP resides on a typical suburban lot measuring 40 ft. x 80 ft. and with no trees around, 30 ft. is the best height that can be attained. While length is important, height should be considered first. In this case, the length of the lot will accommodate a 40 meter half-wave dipole, i.e.,

$$(984/7.2\text{MHz})/2 = 68.3 \text{ ft.,}$$

but will a 30 ft. height permit efficient operation and decent coverage? In order to assess this aspect of the installation, we first determine the electrical height represented by 30 ft. on 7.2 MHz and discover that it is just 0.22 wavelength, i.e.,

$$W = 30 \text{ ft.}/(984/7.2\text{MHz}) = 0.219,$$

less than 1/4 wavelength above ground! Checking a vertical radiation pattern in the Antennabook for an antenna at this height, we find that most of the radiated energy is concentrated between 30-90 degrees, with maximum energy going straight up. At best, the antenna at this height will provide close-in coverage when critical frequencies of the F-region are above 7.2 MHz. As critical frequencies drop below 7.2 MHz, an increasing amount of the radiated energy will escape into space. Then ground-loss enters into the picture, indicating that the antenna at this height will be rather inefficient as compared to the same antenna at greater heights. So, 40 meter operation in this situation is a marginal proposition. On the other hand, if this height is considered for 15 meter operation, this height represents .65 wavelength above ground, i.e.,

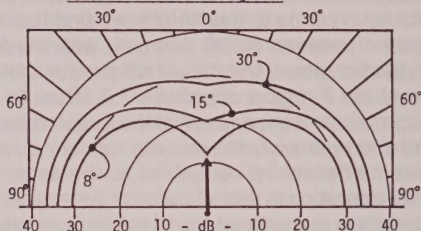
$$W = 30 \text{ ft.}/(984/21\text{MHz}) = 0.65.$$

With respect to the vertical radiation pattern, a major lobe centered at about 25 degrees results with a minimal amount of radiated energy going straight up. Basic coverage is farther out in this case, and at this height, ground-losses are minimal. In other words, the available space and 30 ft. height suggests that 15 meters is the band to concentrate on in this situation. The same height represents .86 wavelength on 10 meters, and since this band exhibits propagation characteristics similar to 15 meters, 10 meter capability would be a logical addition.

(4) Propagation. However, with propagation added to the picture, 15 and 10 meters are usually daytime bands, although during flux levels above 175, 15 meters can remain open far into the evening, and at levels above 200, both 15 and 10 meters can last until midnight and after. So, the choice of these two bands during sunspot cycle peaks would not be much of a trade-off, except with respect to working close-in states. For flux levels below 175, the length of evening openings on 10 and 15 meters decreases as the flux drops, and 120 or so, both bands usually are dead shortly after sunset. And this is where difficult choices appear. 40 meters is usually open to somewhere around the clock during all phases of solar activity, and concentrating on 15 meters during moderate solar phase periods could seem a poor choice because of the loss of late evening openings. However, evening operation on 40 meters is beset with so much foreign broadcast QRM in the midwest and eastern U.S.. that this would be no real loss. The real loss would occur with respect to "wee hours" operation from after 0700UTC until the post-sunrise period. For long-haul work, 40 meters is prime in the few hours before sunrise. After reading around, the Novice would confront a possible solution in terms of the relationship between 40 and 15 meters. A half-wave dipole for 40-15 meters permits optimum resonance on each band. Or, an all-band trap dipole or vertical extends band capabilities to all bands. Or, a horizontal wire antenna fed with open line through a transmatch would permit efficient operation on the high bands, with 40 meters affected only by the low height. In other words, there are a multitude of possibilities for increasing the flexibility in spite of space limitations. Further, if no zoning ordinances are in the way, the effort to gain 50 ft. of height is minimal and approaches are available to fit any budget.

Ultimately, with adequate research, a Novice can settle on an antenna system that will permit making contacts consistently, provide an opportunity for working toward goals such as WAS-QRP, and resolve the problem of how much to spend on a new rig. Hopefully, the preceding discussion will provide Novices with some insight into the factors that should be considered prior to worrying about the choice of rig. As I noted in an earlier chapter, given an outlay of \$500 or so, putting \$350 into 50 ft. of height and an effective antenna will be much more productive than \$490 into a shiny new rig and \$10 change into an ineffective antenna system.

Fig. 1. Horizontal Radiation Patterns
at Given Vertical Angles.



IV. Matching Antenna Capabilities with Objectives.

Assuming that an antenna system is already in place, as in the case of a QRP convert from the QRO ranks, a proposed objective must be weighed against the capabilities of the existing antenna system. The purpose of this analysis is to determine if the present antenna system is adequate to achieve the objective, and if not, to determine the amount of effort and expense involved in bringing the system up to an adequate level. Again, the newcomer to QRP should realize that 100 watts r.f. output makes up for considerable deficiency in an antenna system whereas 5 watts r.f. output cannot tolerate such deficiency. Areas previously worked with S6 signal reports at the 100 watt level will be inaccessible to the 5 watt QRP signal.

(1) Operational Characteristics. The primary operational capabilities of the antenna are its horizontal and vertical radiation patterns, and beyond that, relative gain with respect to the areas to be worked. Assuming that a non-rotatable antenna is either the only possibility or is the existing antenna, it will concentrate radiation in a specific horizontal range of directions, and at specific ranges of vertical angles. Both are quite important factors in QRP operation. Obviously, the antenna must be capable of reaching the geographical areas that are to be worked in terms of the operating objective. In order to assess this aspect of antenna capability, a set of horizontal and vertical radiation patterns for various antenna heights (horizontal antennas) and radiator heights (vertical antennas) is required.

Assessment of horizontal coverage is relatively easy. A tracing of the horizontal radiation pattern can be placed on a map and aligned so as to represent the actual antenna's geographical orientation. Next, the areas covered by the antenna's maximum radiation concentrations can be assessed as "strong signal" areas. Once these areas are established, an estimation of signal strengths into areas not covered by the major lobes can be attempted. For example, consider the usefulness of a typical half-wave dipole at one-half wavelength height in a WAS-QRP project (see Fig. 1). The maximum amount of radiated energy from this antenna is concentrated broadside to the antenna (direction perpendicular to the direction of the wire), and for the vertical maximum concentration angle of 30 degrees, the pattern is quite "broad". On a 40dB maximum scale, maximum field intensity of 36dB is realized across 80 degrees of the pattern north and south of the wire axis. In the direction of the wire, shown as the bold arrow, field strength drops to a minimum of 28dB, a -8dB difference. In practice, then, if this antenna is located in Ohio and is oriented E-W, minimal energy is directed to the east and west, while maximum energy is directed north and south. New England stations will be worked without much difficulty (assuming skip is appropriate), southern stations with maximum radiated energy, as well as stations around the Great Lakes. However, Oregon stations are a long way directly to the west, and the orientation of the antenna results in a starting loss of -8dB in potential signal strength. Because of the great distance to the west coast, this orientation can represent a very serious

obstacle to working midwestern and west coast states, since -8dB is more than an S-unit difference (typically one S-unit = 6dB). No doubt that WAS-QRP could be attained with this antenna, but only with considerable difficulty, especially if operation is on 40-80 meters. Re-orienting the antenna with the wire in a north-south direction places maximum concentration of radiated energy in the direction that needs it, and the close-in states would be little problem even with the -8dB coverage that would result.

(2) Vertical Pattern and Distance.

(Note: the following discussion involves some advanced concepts covered in the propagation and DX'ing chapters of the forthcoming QRP'rs Guide to Transmission Lines/Antennas, Propagation and DX'ing. For the moment, the introduction to propagation found in the ARRL Handbook will provide a general background. The discussion is included here both to provide the newcomer with an example of advanced considerations that can apply as well as indicate some of the practical conclusions that result.)

For horizontal antennas, height above ground and ground conductivity determine the range of vertical angles across which radiated power is concentrated. Vertical antennas typically concentrate most of their radiated power in the range under 20 degrees, but "suck-in" of radiation occurs at under 10 degrees (depending upon ground conductivity), rendering the extremely low angles ineffective. The vertical radiation pattern of an antenna determines the distances that are to be expected in the directions favored by the horizontal lobes. However, the structure of the ionosphere (vertical distribution of ionization) and frequency of operation are controlling factors with respect to distances. In assessing the distance coverage to be expected from a given antenna, these controlling factors are primary considerations.

Several propagation phenomena can be brought to bear in assessing the usefulness of an antenna at 25 ft. (1/2 wavelength) height for 21 MHz operation. Such an antenna concentrates radiated energy in a single major lobe centered at 30 degrees, with useful signal levels occurring from 20-40 degrees. For this antenna to be useful, the ionosphere at reflection points must exhibit sufficient ionization intensity for reflection of a 21 MHz wave in this range of vertical angles. Two separate considerations are involved. First, the critical frequency of the F-region (**foF2**) must be high enough to cause refraction of a 21 MHz signal back to earth. The Cosecant Law permits determination of the minimum **foF2** necessary for refraction of the above range of angles. In this case, for 30 degrees, we find:

$$f_v = f_w / \csc K$$

$$f_v = 21\text{MHz} / \csc(30) = 10.5\text{MHz}$$

(Where f_v = critical vertical incidence frequency, f_w = signal frequency, and K = radiation angle.)

The critical frequency of the F-region must be at least 10.5 MHz for refraction of a 21 MHz wave at a radiation angle of 30 degrees. Solar flux levels approaching 200 are necessary for such a critical frequency. In short, this antenna will be productive during moderately high to high periods of solar activity. During periods of low solar activity, such as now obtain, frustration will be the main result of depending upon this antenna for 21 MHz work. On the other hand, if DX work is the objective and the antenna is capable of low radiation angles (a vertical, or a horizontal at 1 wavelength height), the necessary critical frequency drops back to about 5.5 MHz for a radiation angle of 15 degrees. This critical frequency is possible even at the bottom of the sunspot cycle during mid-afternoons at peaks of the 27 day solar flux cycle.

The second important factor is the presence of an obscuring E-layer and its effect upon low angle radiation during the daylight period. D-region ionization may be adequate for reflection of low angle radiation, thus preventing passage through to the greater heights and hence greater distances possible via F-region

reflections. The Coscant Law permits estimating whether E-region ionization will cancel out long-distance F-region reflections. The following Table presents this relation by listing the highest signal frequency that will be reflected from the E-region for given critical frequencies (**foE**) at specified radiation angles.

The E-region critical frequencies represent low, medium, and high solar activity respectively. By reading radiation angle vs **foE**, the maximum signal frequency that is obscured by E-region refraction can be found. For example, for a mid-day **foE** = 3.4 MHz and a radiation angle = 12 degrees, all signals up to 16.34 MHz will be reflected in the E-region and will not reach the F-region. The result is a much shorter distance (considerably less than 2000km) than would be possible via F-region reflection. During medium and high solar activity, then, a low radiation angle can effectively cancel DX possibilities during mid-day on 20 meters (about 1100-1700 local time at first reflection point, depending also upon path latitude and season). In contrast, a dipole at 1/2 wavelength height will permit 20 meter signals to penetrate the E-region and reflect at much greater F-region heights, producing longer distances and the possibility of working DX paths. Note that during high solar activity where **foE** = 3.9 MHz, 14 MHz signals will reflect for all radiation angles shown in the Table. Note, further, that the common axiom, "lowest radiation angle longest distance," doesn't apply in this case. It is entirely dependent upon ionosphere structure and wave frequency. As solar activity increases, E-region reflections eliminate even the higher bands from access to the F-region. This is the case presented by the right column. A radiation angle greater than 16 degrees is necessary for E-region penetration by a 14 MHz signal. In short, a radiation angle less than 16 degrees can be useless for real DX work on 20 meters during daytime operation at the top of the sunspot cycle.

Of course, the above example represents an assessment for a specific set of conditions — mid-day operation on the high bands and the effect of the E-layer. Flexibility is present because one or more factors can be shifted around to conform to objective requirements. While mid-day operation doesn't look good for 14 MHz, the E-layer is absent during the sunset-sunrise period and the vertical's low angle of radiation then becomes a decided advantage in reaching great distances. In fact, given operation very near the **MUF** (Maximum Usable Frequency), only the vertical's low angles will reflect. Looking at it from another perspective, as **foF2** decreases after sunset, the radiation angles that reflect on the high bands drop and maximum distances increase. Comparing the effectiveness of antennas at 1.25, 1 and 1/2 wavelength, the antenna at the lowest height concentrating radiation at the highest angle will be removed from the field first, then the next highest, and so on. The band will be "open" only to the antennas with the lowest radiation angles at the final stages of drop in **foF2**, and then to none. At sunrise, the opposite order occurs, with the lowest angles experiencing the opening first, and the lowest antenna last. However, path geometry qualifies this general pattern. For example, the path between South Dakota and England covers about 6000km and about 7500km to Eastern Europe. England would seem the easy target because of the shorter distance and the more practical radiation angle required. However, **foF2** variations and F-region heights along the high latitude path (above 60 degrees latitude) are such that England can only be worked during short periods when **foF2** is at its daily maximum and the F-layer height goes through the sunset readjustment at the first reflection point. On the other hand, the path to Eastern Europe supports propagation for longer periods during the afternoon because maximum **foF2** occurs in combination with maximum F-layer heights, together establishing the proper conditions for low-angle reflection at great heights for the longer distance. The situation changes during winter, when global ionization intensity increases and mid-day contact with England becomes possible for longer periods of time. As should be clear from these examples, the dependence of the antenna's vertical radiation pattern upon ionization levels can

Radiation Angle (degrees)	E-Region Critical Frequencies (f_{oE})		
	3.0MHz	3.4MHz	3.9MHz
	E-Region Penetration Frequency		
8	21.85MHz	24.40MHz	28.02MHz
10	17.28	19.58	22.46
12	14.4	16.36	18.75
14	12.4	14.05	16.1
16	10.9	12.33	14.15

be a crucial consideration. Relating all the variables into practical conclusions is a complex task requiring information that is not available in the amateur radio literature (yet). Once the newcomer has gained experience with QRP in stateside operation objectives, he can then turn to DX'ing. A home computer is a definite asset in learning about propagation, since software is available for generating predictions for any path for any specific set of conditions. The standard program for the VIC-20 and C-64 (convertible to other PC's) is "MINIMUF 3.5 HF MUF Prediction Program" by Robert B. Rose (K6GKU), found in **QST**, December, 1982. "MUF-PLOT", a commercial adaptation of MINIMUF 3.5 for a variety of PC's, is available from: Base-2 Systems, 2534 Nebraska St., Saginaw, MI 48601 (1-517-777-5613).

V. Location.

Location can be an important factor in stateside operation objectives, but in DX work, the great distances involved usually require multiple hop propagation and minimum skip distance is not a limiting factor. For example, consider the importance of location in undertaking a WAS-QRP project. In general, areas east and west of the Mississippi represent two different situations with respect to location and WAS-QRP. In the east, states are small and, in places, quite close together, so much so that a skip distance (minimum) of 600km will carry a signal over a couple neighboring states per hop. However, the close-in states are as important as the distant ones in WAS-QRP. In considering such a project, a location in New England can force all other factors into place. Given the really short distances involved, operation on 80 or 40 meters would be almost mandatory, even if this involves an inefficient antenna at 25 ft. height. Actually, the low height could be beneficial in terms of the high angle path geometry required. Daytime on 40 and nights on 80 would produce the desired contacts without too much difficulty. High population density in the east is another location factor than can affect choices. The usually high level of activity (as compared to less populous areas) provides more opportunities to select stations to call. However, in the event that 80-40 meter operation is impossible (actually, nothing is impossible as long as wire is available), the limitations of the high bands have to be seen as a very serious obstacle at this location. During the top of the sunspot cycle, daytime 20 meters is often capable of reflecting the high angles required for short skip distances, but high **foF2** levels are a must in combination with low virtual heights. For working very close-in on 14 MHz, both high **foF2** and the low virtual heights of the winter season are a must, with high solar activity included in the bargain. Trying WAS-QRP on 14 MHz from an eastern location during sunspot cycle lows would be quite unrealistic! It should be noted that this is generally true, and that ionospheric behavior is such that very close-in work is possible on 14 MHz, given the right combination of conditions and a lot of patience. However, as noted earlier, the distances involved for midwestern and western stations make high band (at least 20 meters) operation for WAS-QRP reasonable during the top half of the sunspot cycle.

In addition, location can be important in approaching special activities such as contests (stateside). Here, the scoring system is important. The QRP-ARCI Spring and Fall QRP Contests use band multipliers (i.e. Arizona can be worked on six different bands and add 6 multipliers to the total score). Such a scoring system encourages the QRP operator to make an effort toward multi-band capability, and location determines operating strategy with an emphasis on operating on a band which is likely to add new states for multipliers. In some contests like Field Day, no state multiplier is used, and the objective is to make as many contacts as possible. In this case, location focuses strategy differently. If it is possible to work stations continuously on 40 meters, there is no point in changing bands. Finally, in DX work, the high bands must be used by the QRP operator, and the relationship of the QRP's location to other areas of the world is defined primarily by propagation variations.

VI. Band Selection

Band selection is a matter of matching an objective with the propagation characteristics of the band most suitable for the distances desired and the available operating time match-ups. Overall, propagation characteristics are related to the level of solar activity, the season, times of operation, and the direction and latitude of the path. With respect to stateside operating objectives, the basic limiting factor as to the usefulness of a given band can be minimum skip distance, while in DX'ing or working distant states, the main consideration can be the ability of a given band to support low-absorption, long distance propagation. Regardless, the propagation characteristics of the various h.f. bands relate directly to ionization intensity levels which are controlled by the level of solar radiation intensity. With respect to absorption, D-E region ionization is the major factor, and in regard to coverage distances, E-F region critical frequencies and virtual heights are the important factors. In assessing usefulness, the following sections are intended to show how basic propagation principles can be applied in a general summary of band selection considerations.

(1) Low Bands — Daytime Operation. During daylight periods, D-E region ionization is present and exhibits zenith angle control. During winter months, the sun is in the opposite hemisphere with the result that the noon zenith angle (smallest of the day) drops to 23 degrees + northern latitude (critical frequencies and MUF are inversely related to zenith angle — the larger the angle, the lower the MUF). During summer, with the sun in the northern hemisphere, the zenith angle at noon can drop to nearly 0 degrees for southern states. D-layer absorption and E-layer critical frequencies respond accordingly. Thus, **foE** rises above 1.8 MHz (160 meters) quite rapidly following sunrise, and a few hours later, approaches or exceeds 3.5 MHz (80 meters). Hence, daytime 160-80 meter operation is almost exclusively via E-layer reflections and in theory can extend out to the 2000km limit for paths via E-layer minimum virtual heights in the vicinity of 80-110km. However, D-region critical frequency is not far below 1.8 MHz and hence daytime absorption is extreme, on 160 meters, with 80 meters not much better. Thus it is virtually impossible to make use of the maximum range of E-layer coverage, since low radiation angle paths spend considerable time in the D-region where absorption is more than enough to wipe out a QRP signal. Very short skip distances are possible though. During the transition and bottom portions of the sunspot cycle, daytime 80 meters can be useful out to 800km or so in winter, provided anyone is on the band. Usually no one is.

7 MHz signals suffer four times less absorption than 3.5 MHz signals and are usually twice **foE**, so that E-layer reflections can occur up to the 25-35 degree radiation angle limit. For the QRP operator, absorption is a factor, but daytime operation out to 1200km or so is possible during periods of low solar activity.

Absorption increases considerably during sub-peak and peak portions of the cycle, but distances out to 800km are practical. Because **foF2** is typically above 40 meters during most of the solar cycle, very short distances are available via very-high angle F2 reflections.

(2) Low Bands — Night Operation. From sunset to sunrise, the three low bands develop into excellent QRP bands. Depletion of D-E ionization eliminates the high daytime absorption and the obscuring E-layer, with reflections from F-region night virtual heights. With sunset, F-region virtual heights begin readjusting upward while **foF2** begins its slow decrease toward pre-sunrise lows. The effects of these two F-region variations become more noticeable as operating frequency increases.

(a) On **160 meters**, signals begin emerging from the noise level (depletion of D-ionization) during twilight and a slow but steady increase in signal strengths continues until about 2300 (local time). At the same time, reflection distances slowly increase from about 300km as F1-F2 layers combine into the night F-layer and reach a stable virtual height which prevails from about midnight onward. For an eastern station, the growing skip distance keeps pace with the westward movement of twilight and darkness, with eastern stations being heard to the west before the path optimizes toward the east. Depending upon solar activity and season, the South Dakota-Vermont path can connect as early as 2200 South Dakota time. Since **foF2** is always above 1.8 MHz, very short distances are possible at night on 160, with the only limiting factor being the vertical radiation patterns of stations at either end of the path. The transition and bottom portions of the solar cycle are considered the best for long distance work, although experience shows that 160 experiences DX openings at all points in the cycle. Operation on 160 during summer months is severely limited by the usually extremely high noise level due to atmospheric electrical activity. Weather forecasts of thunder shower activity usually suggest a cancellation of 160 meter operation for a night or two. However, for the QRP operator, 160 meter DX means 3000km DX, not real foreign DX. An excellent antenna is required for “reaching out” to such distances. But marginal antennas at relatively low heights allow for good rag-chewing with close-in stations. Finally, the pre-sunrise period is optimum for long-haul work, and the band disintegrates shortly after dawn.

(b) 80-40 meters exhibit similar night variations, with 80 meters more like 160. On **80 meters**, skip noticeably begins lengthening as a sunset moves across the country, and signal strengths increase at a faster rate than on 160. During sub-peak and peak cycle years, **foF2** remains considerably above 3.5 MHz even at the pre-sunset dip, and as a result, 80 meter signals reflect at F-layer minimum virtual heights with little or no penetration, resulting in negligible deviative absorption and excellent long distance QRP work. Technically, residual D-E ionization during these years should hinder QRP long-distance work on 80, with overall better QRP prospects during transition-bottom cycle years, but veteran QRP operators reject this view on the basis of experience. Two-way QRP transcontinentals are a reality on 80 meters even with the incredibly poor antennas that are used in “let’s give 80 a try with the 40 meter dipole” operating excursions. With effective antennas, “transcons” are consistent, although not easy. As on 160, the range of coverage extends from the antenna outward, with next-door skip possible, and limited only by vertical radiation patterns. 80 meters improves as evening progresses and remains relatively stable after midnight until sunrise. During winter months, east coast QRP’rs have a decent shot at European DX if an excellent antenna is used. West coast QRP’rs have shots at VK, Oceania, and JA. In the former, local midnight provides the time match-up, while in the latter, local sunrise. Midwestern QRP’rs usually must be contented with hearing DX from both directions, working neither, and settling for the Caribbean now-and-then. “Alas,” saith W0RSP.

(c) **40 meters** is much more dynamic than either 160 or 80 meters following sunset. The dynamic instability of the F-region is responsible for post-sunset 40 meter idiosyncratic behavior which includes sudden QSB with troughs down 2 S-unit. At sunset and the collapse of D-E ionization, QRP'rs have a front seat on the F-region rollercoaster and it can be a very exasperating experience. Coverage begins increasing rapidly with sunset, but this is not a smooth process; rather, it is jerky. After an hour or so, decreasing E-ionization permits greater penetration of moderate angle 40 meter signals. During this period, 40 meter signals are going through an ionosphere in the "tumble-dry" mode and are bounced all over the place. QRP operation in the post-sunset period is undependable until the ionosphere settles down around 2200 or so, depending upon solar activity and season. After 2200, transcontinental work with QRP is possible and routine, though difficult at times, provided a dipole at 50 ft. is available. With marginal antennas like a dipole at 15 ft., California signals can reach South Dakota at 53-54 levels, and frequent QSB puts them in the noise. My vertical pulls 57-58 reports though. Beginning in late evening, QRP DX work emerges as a possibility for east coast to Europe contacts, with the same patterns as noted above for 80 meters.

(3) **Seasonal Variations.** During the summer season (approximately mid-May to mid-September), **160 and 80 meters** are frequently rendered worthless for QRP due to atmospheric noise (QRN) and thunderstorm activity which obliterates both bands during the day. Night conditions provide some improvement, but QRP operation is seriously hampered by local and distant thunderstorm activity, heat lightning, and other atmospherics. For the QRP operator, summer 160-80 meter operation depends upon signal-to-noise ratio, and a really effective antenna is necessary for bringing the QRP signal up above the noise. Generally, few amateurs care to fight summer QRN and band occupancy is quite low. There are still some "tube-hound" hand-key old-timers who grew up operating on 80 meters, and get on the air regardless of season and noise levels. The Novice band usually has a few comers. During the remainder of the year, the noise situation gradually improves until an essentially quiet daytime 80 meters occurs frequently. However, virtually no activity occurs. 160-80 meters are in their prime for night operation during the winter months though, and remain so until late spring (April-May). Operating on these bands during the winter season from about 2200 on is a real QRP treat. Signal strengths are usually quite stable and excellent distances possible.

40 meters is subject to the same daytime problems as 160-80 meters during May-September (summer). However, even on summer days when the "phones sizzle" with background QRN, relatively lower absorption levels result in better signal-to-noise odds and daytime 40 meter QRP work is feasible for short-distance, one-hop work. At low radiation angles, the QRP signal loses out to absorption and noise. Night operation is beset with the same problems as noted above for 160-80 meters, but during the winter season, 40 comes into its own for long-distance QRP work. Activity is usually higher than on 80, although the presence of strong foreign broadcast stations during the evening can make life difficult. During transition and bottom years of the sunspot cycle, activity increases considerably on 40 after 20 meters closes down during darkness hours. An effective low-angle antenna can produce almost routine transcontinentals during winter nights on 40. Minimum skip, however, can vary considerably with solar activity. During low parts of the sunspot cycle, 1200km can be the minimum, although during cycle highs, very close-in work is possible. In general, the low bands improve slowly during late fall as winter ionization builds up to December highs and February peaks; excellent conditions persist until May or so.

(4) **High Bands and Flux Levels.** 20, 15, and 10 meters are essentially daytime bands, with the extent of their usefulness depending primarily upon F-region behavior and the levels of solar and geomagnetic activity. The length of daytime

openings on the high bands is directly related to diurnal and seasonal variations in **foF2** and F-region virtual heights. Openings increase in duration in direct proportion to the trend of solar activity as indexed by the 10.7cm solar flux emissions. At the same time, geomagnetic activity exerts a depressing influence that counteracts the improvements that could occur from rising flux levels. Both the solar flux and geomagnetic activity exhibit 27 day cycles corresponding to the rotational period of the sun, but fortunately, the cycles are not in phase (i.e., the flux may be rising to a 27 day peak while the geomagnetic activity level is bottoming out). Flux variation is rather smooth in either the rising or falling portions of the 27 day cycle, but geomagnetic levels are erratic in variation. In short, the duration and usefulness of the daytime high bands increases in step with flux increases so long as geomagnetic activity remains low or decreases. The flux-geomagnetic activity relationship is not critical with respect to stateside work, but QRP DX work depends upon low levels of geomagnetic activity except during very high solar activity. With respect to planning operation in the context of a specific objective, the current level of solar activity can be used as a simple criteria for assessing high band performance. In the following paragraphs, several levels of solar activity are assessed for the high bands, and are conservative when low geomagnetic activity is present (i.e., A-index at 10 or below, K-index at 2 or less). Both the solar flux number and the current A-index and K-index numbers are broadcast over WWV (5, 10, 15, 20 MHz) at 18 minutes past the hour. They also may be obtained by calling the Dial-a-Prop number: 1-303-497-3235.

20 Meters. Generally, 20 meters opens at or shortly after sunrise and remains open until after sunset during all portions of the sunspot cycle, with closing times pushing farther into the night as the solar activity level increases. During sub-peak/peak years, 20 meters can remain open around the clock from May-September, with the length of night openings diminishing as winter progresses. During the bottom of the cycle with flux levels under 90, 20 meters is frequently the only high band that is consistently open. Because of relatively low **foF2** at this point in the cycle, ionization is inadequate for reflection of the radiation angles required for distances of less than 1000-1200km. Increased winter ionization levels and lower virtual heights, however, permit path geometries in to about 800km. Absorption is not a significant factor even during low zenith angle summer periods. Hence, daytime 20 meters is the QRP band for working distant states or DX during low solar activity. It is the principle band for QRP DX work, and seasonal variations affecting times and duration of openings on major paths are important considerations.

As the flux value moves upward through 135 or so, 20 meters improves in length of opening time and can remain open all night at this level. It is useful primarily for DX work with one-hop 4000km coverage as the MUF drops during the night. Late evening and night openings are useful for high-latitude and polar paths only with the A-index at very low levels. Daytime skip distances decrease in step with increasing **foF2** to a minimum of about 600km. As the flux level moves above 165, MUF's rise considerably above 14 MHz, and daytime absorption has noticeable impact on QRP signals. With geomagnetic activity above 15, daytime 20 meters can be a losing QRP proposition even with very high flux levels, although very close-in work becomes possible. During peak years, the standard band selection axiom — operate on the highest band that is open at the time — has definite relevance to daytime 20 meter operation. However, sunrise and post-sunset periods often provide excellent QRP DX openings during sub-peak and peak cycle years.

15 Meters. A flux level of around 105 is necessary for worthwhile 15 meter QRP operation, even though a flux of 95 will produce openings. At this low level (105), 15 meters generally opens a few hours after sunrise, depending upon season, and begins deteriorating shortly before sunset reaches the mid-path area.

Absorption is practically non-existent, making 15 meters the most effective daytime band for stateside QRP work aimed at stations more than about 1400km away. Close-in work is impossible, except during **Sporadic-E (Es)** occurrences.. At this activity level, 15 responds quickly to twilight conditions along the path, and the band can close to an area in 10-15 minutes. As flux levels move through 150, 15 meters opens to the east shortly before sunrise and signal levels peak fairly rapidly. Stateside QRP work is easy with even a simple dipole throughout daylight hours. Novice band activity is usually high, with many strong signals present. The major hindrance is a lack of radiation angle match-up between stations. Otherwise, milliwatts will produce contacts consistently. Because of increased **foF2**, skip shortens in step with rising solar activity levels. The band remains open into the evening at these flux levels. For example, during bottom years of the cycle, W0RSP frequently worked late evening (2200-2300 local time) DX such as KH6, VK3, and FO8 during flux peaks of 132 rising out of a long-prevailing flux level below 90. The night openings are useful primarily for DX work. When the flux level rises into the 200's, absorption effects on daytime 15 meters become quite noticeable in comparison to 10 meter absorption levels. However, DX work is still possible. At these levels, 15 meter openings can extend past local midnight. During cycle 21 peak years, W0RSP found 15 meters producing consistent DX contacts to the west as late as 0100 local time.

10 Meters. 10 meters begins opening with some reliability when the flux rises above the 115 level. Several hours of sunlight are required before 10 really stabilizes in late morning, and openings endure until late afternoon for paths to the east. Skip distances of about 1500km are the shortest to be expected, although summer Sporadic-E occurrences produce very close-in skip. The propagation columns in **CQ** and ham radio and "The World Above 50 MHz" in **QST** are excellent sources of information about expected Sporadic-E activity. The expected daily patterns of **Es** are noted, but where the **Es** openings will occur cannot be predicted. The operator simply has to check 28 MHz on days of predicted activity. Once **Es** gets underway, most close-in paths eventually open for a while. The QRP'r has to be there waiting.

Response to twilight conditions along the path are rapid, with stations going into a rapid QSB and then dropping into the noise in a matter of minutes. The duration of daily openings increases with solar activity levels. As the flux reaches the 180 mark, 10 meters opens at sunrise and remains open into the evening hours. DX work to the west is possible as late as 2100-2200 local time. Daytime skip shortens to the 1100km range. With the flux rising past 210, 10 meters opens with sunrise and remains open to midnight and later to the west. Polar cap absorption events can result in high-latitude openings to the east after midnight. Transequatorial paths can be functional almost all night at levels above 250. With these high flux levels, the QRP DX operator can have the most exciting operating experiences of his career on 10 meters.

30 Meters. The new 30 meter band shares high and low band characteristics. Summer noise is not as bad as on 40, but absorption is higher than on 20. QRP DX work is possible at all seasons, although the daylight/night shifts are not as marked as the high bands. 40 meter rollercoaster behavior accompanies the sunset period. Occupancy is low, and power limited, so QRP is quite effective. However, a recent FCC Rule Making Proposal would increase the power limit to the full 1500w p.e.p., turning this otherwise very satisfying QRP experience into the usual bedlam of S9 + 40dB signals. My experience on the band is not extensive enough to justify further comment, other than to note that 30 meters provides a relaxed, non-competitive and civil atmosphere.

Overall, I should note that the above paragraphs are based upon observations of propagation between South Dakota and various parts of the world. I hope that this chapter alerts newcomers to the need for thoughtful planning as a prelude to

QRP operation. I am certain that many would-be QRP'rs have been "burned out" on QRP simply because they did not give QRP a fair chance through planning. The "let's see what QRP can do" attitude is acceptable for a couple of shots with the QRO rig backed off to 5 watts. But that is all it is good for! The QRP operator must offset his power disadvantage through knowledge and skill, and above all, patience. Actually, trying QRP without learning about antennas and propagation almost guarantees frustration, as we've noted earlier. Only when the QRP'r knows what is going on in the ionosphere and what to expect from his antenna on various paths at various times will frustration disappear. Then he'll taste the "Joy of QRP'ing" in its fullest and be able to take the credit for his successes. This chapter has presented many "think it through" examples, and some admittedly require more background information than is included. That is part of the process — learning to recognize when you don't understand the principle behind the analysis, and then heading for the **ARRL Handbook** or **Antennabook**. Propagation is different at every location, and every antenna is a different antenna at a different location. The only way to understand your particular situation is by knowing the principles that apply, and then thinking it through! To move on, once planning is underway, the next task is getting a QRP signal on the air. We'll devote the next two chapters to that subject, and then discuss operating techniques for successful QRP'ing.

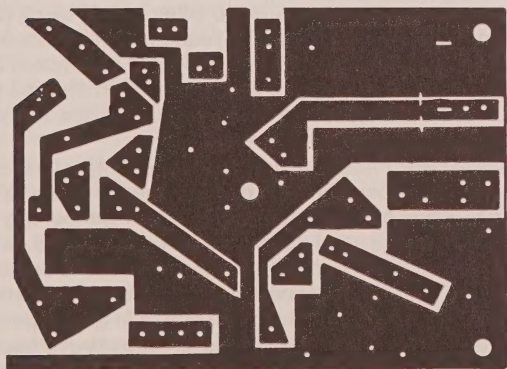
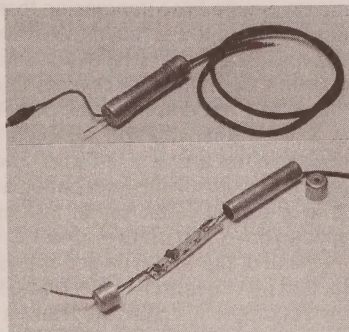
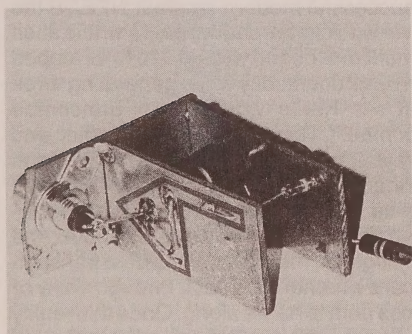


FIG.15

Chapter 4

Putting a QRP Signal on the Air: Commercial Gear

Once an operator decides that QRP is the kind of radio operation that he wishes to pursue, the practical problem of “getting started” inevitably crops up. Actually, getting started in QRP is a simple proposition. As writers in the early days frequently pointed out, low power isn’t a rich man’s game. In fact, low power inevitably means low cost because many of the expensive elements of a high power station — high current d.c. supplies, expensive high power tubes and transistors and such — are simply not needed in low power installations. Kruse’s ideal applies to low power operation even today — not a BIG station, but a GOOD station.

The list of basic equipment for a good QRP station is short: a transceiver or discrete receiver/transmitter combination capable of generating up to five watts r.f. output in the desired bands and modes, a means of measuring r.f. output power, such as an r.f. probe with VTVM/FETVM/DVM or in-line wattmeter, and a few essential accessories, such as a key or keyer, headphones, and perhaps an antenna tuner. Unfortunately, the ads and pictures in the ham magazines often create a quite false impression that the successful modern amateur NEEDS the latest state-of-the-art solid-state transceiver with digital readout plus a whole shelf of accessories, or that he needs a six element monoband yago at 120 ft. all topped off with a linear that can operate key-down until doomsday while generating three times the maximum legal power limit. As Kruse would say, “Buncombe Brother — absolute and complete Buncombe!” The operator on the other end doesn’t know and doesn’t care how shiny your transceiver is or how many knobs and meters are on the front panel, and further, he can’t tell! All that he is interested in is a stable, clean signal that carries its information in well-formed evenly-spaced c.w. characters or clean undistorted s.s.b. That’s all he cares about. And that kind of signal can be generated by the ugliest, most beat-up, oldest transmitter that can be found — electrons don’t care whether they flash through shiny or dirty equipment, just so they have a low-loss path to hurtle along. Once this reality is accepted, it will be possible to achieve an equipment-purchasing flexibility that permits entry into QRP operation on any budget.

The beginner has three options with respect to the purchase of the basic receive-transmit capability: (1) QRO gear consisting either of separate receiver and transmitter, or a transceiver, purchased either new or used; (2) commercially produced QRP gear, either new or used; (3) equipment constructed by the operator himself. Given this range of options, a budget of from about \$75 to the outer limits will enable the operator to put a decent signal on the air. Let’s discuss the first option in practical terms, saving our discussion of how to use QRO gear for QRP operation until later in this chapter.

The prospective QRP’r has a virtually unlimited range of transmitters, receivers, and transceivers to choose from because nearly every QRO transmitter/transceiver can function at QRP power levels, often without any modification to the unit. Fortunately, a large used equipment thrives in the U.S., where every conceivable piece of gear can be purchased, usually at a considerable savings over the the new price. Buying “used” is not a high-risk proposition in the context of the savings that are possible, provided a given unit is in good operating condition. Often, the purchase price (used) plus the cost of a factory overhaul and alignment will not raise total expenditures anywhere near the price of a new unit. The used market goes way back and has available many of those “oldies but goodies” from

tube days. Purchasing a unit produced in the late 50's and early 60's may seem risky to the newcomer, but it isn't. Using early equipment is a bit inconvenient, since a station in those days was comprised of a separate receiver and transmitter and required tuning both onto the operating frequency in order to call a station. But there were definite advantages to the discrete approach. A receiver was designed to serve one purpose as effectively as possible — receiving incoming signals — and those units contained features that must be purchased as extra-cost options on today's transceivers. The same was true of transmitters. Another very important cost savings is due to the fact that, back then, a power supply was built into every unit; Modern gear from the early 70's onward often requires an external power supply unit. An important consideration is that it is possible to purchase a top-of-the-line, high quality "built to last" receiver or transmitter from the 50's and 60's for a song. Names like Collins, Hammarlund, RME Engineering and Gonset represented the standards of engineering excellence and production quality in their day. Many such companies no longer exist because they refused to cut corners to produce saleable but slightly less effective units. For example, I purchased a Hammarlund SP-600-JX21 at the auction of National Radio's main assembly line back in 1971. A general coverage type receiver from the early 60's covering 0.55-55 MHz with numerous features, the SP-600 is built like a battleship and even though 20 years old, it will sit within 200 Hz of WWV at 10 MHz for days on end! Price? \$135. Ridiculous. I wouldn't trade it for anything. Picking up a Collins 75A3 hamband receiver for under \$200 can't be a mistake if the unit is in good shape. It was just the best in its day!

Whether the decision is made to buy new QRO gear, or older used gear, shopping around requires some familiarity with sources of information about prospective purchases. **QST** and **CQ** have carried advertisements describing gear, and these can be checked if available. Otherwise, the best source of information is A.L. Brand's compilations included in **Ham Equipment Buyers Guide**. Vol. I covers receivers, transmitters, and transceivers from 1945-1972 with 900 pictures, 166 pages, for \$7.50; Vol. II covers the period 1972-1975, 100 pictures, 28 pages, for \$3.25. "Update sheets" covering years to 1978 can also be ordered at \$1.50 per year. From A.L. Brand, c/o Barbara Brand Wixon, 189 Kenilworth, Glen Ellyn, IL 60137 (check made out to Wixon). Used equipment advertisements are carried by all the major ham magazines. However, ads appearing in this source are often 2-4 months old. I've been disappointed quite a few times when I excitedly called long distance about one of my "dream buys" found in the want-ads only to be informed that the item had been sold at a flea market two months earlier. This isn't always the case, but it happens frequently enough. The best source of fresh 2-3 weeks-old is the "Ham Trader Yellow Sheets," so-called because they are mimeographed on yellow paper, and are commonly referred to as the "yellow sheets". Published by A.L. Brand, PO Box 356, Wheaton, IL 60187; current subscription is 24 issues (1 year) — \$7.00, 50 issues (2 years) — \$14.00. The "yellow sheets" are where the buying-selling action is. Hamfests and flea markets provide excellent opportunities to find good buys or to familiarize oneself with various units. Finally, local amateurs at the club are often an excellent source of information and advice about various units, and as often as not will lend or sell an unused piece of gear to a beginner to help him get started in amateur radio.

I. The Used QRO Transmitter/Transceiver.

A beginner can become totally overwhelmed when confronted with purchasing his first rig, especially if he knows next to nothing about radios. It is helpful to know what to look for in searching for and purchasing good used equipment. The following comments should be helpful. Generally, there are certain features and specifications that should be kept in mind with respect to used QRO transmitters

or transceivers purchased with the intention of operating at QRP levels. Some of the features and the logic underlying their importance follow.

(1) V.F.O. Control. QRP operation requires the flexibility of moving the transmitter to the frequency of another station, since few modern operators are in the habit of responding to a weak-signal "CQ", assuming incorrectly that propagation is poor. Hence, the primary feature to look for is v.f.o. control. However, back in the 50's, quite a few transmitters that are ideal for QRP operation were marketed with crystal control. These include units such as the Heath AT-1 (30w input), DX-20 (40w), DX-60 (90w), Globe Scout (65w) and Viking Adventurer (50w). Decent examples of these units often show up at hamfests for as little as \$15 — as cheap as can be for an all-band transmitter! Discrete v.f.o.'s were also marketed during that period and will match up with these transmitters. V.f.o. units include the Heath VF-1 and HG-10B, the Hallicrafters HT-40, and others. Some v.f.o.'s will do excellent service as 3-5 watts output QRP transmitters.

(2) Bands. Most commercial gear on the used market covers 80-10 meters, although some of the older units also include 160 meters, such as the Viking Ranger and Navigator, the Elmac AF-67, and Lysco 600. All-band coverage is, of course, a definite advantage.

(3) Modes. Prior to the advent of s.s.b. in the early 1960's, the typical transmitter featured c.w./a.m. modes capability. Today, a.m. is useless, and these transmitters will be useful only for c.w. operation. This is not a real limitation, since it seems that the majority of QRP operators go the c.w. route anyway. By the mid-60's, the shift to s.s.b. was underway, and if s.s.b. operation is intended, verify that a given unit can be operated in the s.s.b. mode before buying it.

(4) Power Supply. In the days of separate receiver and transmitter amateur stations, nearly every commercial unit included a built-in power supply. Very few exceptions such as the Elmac AF-67 or Heath HX-20 will be encountered. With the movement to transceiver designs in the mid-60's, stuffing both receiver and transmitter into a single cabinet eliminated the integral power supply in most cases. Today, few commercial transceivers are on the market which include an internal power supply. A power supply unit can cost as much as \$175 used! Don't be taken in by a fantastic price in an ad that omits mention of the power supply. For example, one recent yellow sheet contained ads for two Heath SB-104's (a top of the line c.w./s.s.b. transceiver with digital readout and a 1-watt low power function position, also produced as the HW-104 without the digital readout feature) with prices of \$585 and \$460. The second price looks like an absolute steal, except that the ad for the first price specified "w.p/s" (with power supply), and the second ad omitted mention of the item. A phone call would probably reveal the catch to the second price — \$460 for the SB-104 alone, no power supply included. Always verify that the supply is included in the price.

(5) Power Control. Since QRP operation with QRO gear is intended, it is very convenient to include as a feature some built-in power level control that can be used to lower output power to QRP levels, or nearly so. Older tube-type transmitters often included a TUNE function, and in this position, the units developed anywhere up to about 10 watts r.f. output, and hence are easily used at QRP power levels. Second, many tube rigs used an adjustable PI-network between final amplifier and antenna. This highly desirable feature permitted feeding antennas exhibiting a wide range of impedances, but more important, permitted raising or lowering amplifier r.f. output across a fairly wide power range. The presence of such a matching network in an older tube transmitter or transceiver is indicated by two amplifier tuning controls on the front panel, one of which adjusts the final amplifier end of the network, while the other adjusts the antenna end. These controls are variously labeled "PA PLATE, LOAD", "PA TUNE, PA LOAD", "FINAL PLATE TUNE, FINAL LOAD" etc. Unfortunately, cost-cutting in the 1970's has eliminated the matching network in the modern transceiver, with the

result that such units will match only a narrow range of antenna impedances — if a matching network or transmatch is necessary, it must be purchased separately. Progress — Buncombe! Third, almost all units include some form of drive control which can be used to drop output power to QRP levels. These are labeled DRIVER TUNE or simply DRIVE in older units, but more modern c.w./s.s.b. transceivers frequently label the drive control as MIC GAIN.

(6) Power Level — D.C. Input Rating. Until very recently, transmitting gear was rated in terms of d.c. input power to the final amplifier. Generally assume anywhere from 20% to 50% efficiency (output divided by input). Obviously, a unit rated at 500 watts d.c. input will be practically useless as a QRP transmitter. However, because of certain market and design traditions, units ranging up to 180 watts (tube type) or 200 watts (solid-state type) can usually be employed at QRP levels. This is due to the fact that the amount of r.f. drive power to the final amplifier required for rated d.c. input usually and conveniently falls within the QRP range — the driver stage, in other words, is a ready made QRP transmitter.

(7) Driver-Final Tube Line-up. Hence, it is often valuable to determine the types of tubes found in the driver-final amplifier stages of a transmitter unit. Typically, tube rigs rated at 180 watts input used a pair of 6146's, 90-100 watt units used a single 6146, 75 watts used an 807, and 40 watt input units used a 2E26 or a beam-tetrode T.V. type tube. The driver tube typically was a 5763, capable of about 8 watts output, a 6CL6, capable of about 5 watts output, or any of the variety of tetrodes/pentodes designed for T.V. use, such as the 6BQ5, capable of 17 watts output. Two routes can be followed with such transmitters, and these will be discussed below. Some really old rigs used 6V6's and 6L6's as driver tubes — these are difficult but not impossible to replace — yet.

(8) A Few Good Choices. Down through the years, quite a few really neat transmitters and transceivers have been marketed which lend themselves naturally to QRP operation. This is especially true of the pre-s.s.b. days when 150 watts was high power and most guys ran under 75 watts input. Several v.f.o. controlled, all-band transmitters useful for QRP c.w. operation are worth snatching up on the spot. One of my boyhood dream rigs was the Johnson Viking Navigator, a beautiful little 40 watt c.w. rig that could be put into service immediately in QRP operation. Likewise, its bigger brother, the Viking Ranger, an all-band c.w./a.m. unit rated at 75 watts input, was extremely popular during the 50's and early 60's and literally was the "workhorse" of amateur radio. Many are still in operation and appear on the used market in the \$75 price range — an excellent rig requiring no modification for QRP operation. The Elmac AF-67 (40w) was designed for mobile use in combination with the miniature (for tube days!) companion receiver, the PMR-6. The units require an external power supply, but AF-67's pop up at anywhere from \$25-60 infrequently, with PMR-6A's in the same price range. A pair for \$75 would be a bargain QRP station. The same is true of the Harvey-Wells combination T-9 (90w) and R-9 all-band mobile station marketed in 1955. Both can be operated from an external 12v d.c. supply, or the built-in a.c. supply.

Several 180 watt range transmitters appear on the used market and are worth considering, although prices approaching \$200 make them a considerable investment if used only for the c.w. mode. It would be advisable to stick to units produced in the mid-60's capable of both c.w./s.s.b. operation. Hallicrafters marketed a continuing line consisting of the HT-32A, HT-37, HT-40, HT-44 and HT-46 (matching SX-146 receiver) worth looking at for around \$150. Gonset's GSB-100 transmitter was an excellent design and surfaces at around \$135 periodically. Likewise, Hammarlund's HX-50 (HQ-170A companion receiver) is a good one. Barker & Williamson produced an advanced-design BW-6100 for a while. Heath units such as the SB-400 appear at around \$150, while the earlier HX-10 Apache and HX-20 (90w, no p/s) can be found usually for under \$100.

Similarly, transceivers began appearing in the mid-60's for c.w./s.s.b. operation, beginning with SBE Engineering's SB-33 and SB-34, both of which include self-contained supplies. Drake's TR-3 is at good buy at \$300, provided supply is included. Hallicrafter's SR-150 and SR-160 would be good at \$300 (with p/s). Heath turned out a continuing line of transceivers such as the HW-100 series and SB-100 series that appear frequently at low prices. National's NCX-3 and NCX-5 are decent units for \$300 (w. p/s). More recent transceivers, if in good condition, usually break the \$300 price range considerably.

II. The Used Receiver

The used market offers an even wider variety of receivers to choose from. This may lead initially to some confusion for the newcomer in a search for a receiver, but it is actually an advantage because receivers by Collins, Hammarlund, Drake, RME, and top-of-the-line units by Hallicrafters, National, and others will provide excellent performance at very reasonable cost. With respect to strategy, the newcomer to amateur radio should seriously consider purchasing a high-quality used receiver before getting a commercial transmitter. The reason for this strategy is quite simple: homebrewing a simple solid-state transmitter for a single band, or several for several bands, is by far an easier task than building a multiband receiver. If this approach is taken, the high-quality receiver will help the newcomer sort out close-packed signals and render the difficult task of copying c.w. at first quite a bit easier. Then too, everyone ought to build at least one functioning transmitter, and this is an excellent opportunity for the beginner to do it. Two general categories of receivers will be encountered.

General Coverage Receivers. General coverage receivers designed and produced for the commercial and military markets include such top-quality units as the Hammarlund SP-600 series, and the Collins 51J-/R380/R390 series. The general coverage receiver usually has a frequency range of from 0.55-32 MHz (or 54 MHz in the SP-600 case), with a main tuning dial and a separate dial for bandspreading. The only drawback in the Collins series and Hammarlund SP-600 units is the lack of hamband calibration on the dial. However, given the performance and quality of these units, it is well-worth the extra effort required to add some form of mechanical hamband bandspread, such as I described in "Cheap and Easy Bandspread for the SP-600-JX" (CQ, April, 1976). These units include a variety of features and can serve as lab test equipment because of their calibratable S-meters, frequency range and stability. The general coverage receivers produced for the amateur/SWL market usually include a separate bandspread dial calibrated for each of the amateur bands. The obvious advantage of such a unit is that it can serve the dual purpose of amateur operating, monitoring signal purity, and SWL'ing without modification. Among these are the Hammarlund HQ-series (HQ-170, HQ-180, and the solid-state HQ-215), the Galaxy-530, and the National NC-400.

Amateur Band Receivers. Until the 70's, the amateur band receiver was the major product of several companies which offered complete lines of receivers ranked according to price and quality. National Radio, Hallicrafters, and Hammarlund were leaders in the field. Other companies such as Heath, Drake, and Kenwood produced amateur band receivers as companion pieces for their transmitters, as with the Heath SB-300/SB-400, Collins 75A-/32V-series, the Drake R4/T4, Kenwood R-599/T-599, Hallicrafters SX-146/HT-46, and others. Generally, the companion type receiver was a top-of-the-line unit and worth it.

Transceivers. The receiver sections of transceivers, naturally, are ham band receivers, and depending upon the quality of the design, usually sacrifice some flexibility for the sake of integration with the transmitter section. More specifically, the use of a single wideband i.f. filter for generating s.s.b. signals (usually 2.1 KHz

or 2.4 KHz) which doubles as the receiver i.f. filter seriously limits the usefulness of the receiver section of such a transceiver for c.w. operation, as we will note in detail below. There are certain features that are desirable in a receiver, and the following list surveys the most important:

(1) Coverage. The first decision to make in searching for a used receiver is whether to select a general coverage, general coverage with hamband dial, or a hamband-only receiver (or transceiver). The first types offer advantages that make them worth considering. First, a general coverage receiver permits SWL'ing (shortwave listening) to foreign broadcasts and monitoring WWV for time checks and propagation bulletins at 18 minutes past the hour. Second, the general coverage receiver can function as a valuable piece of test equipment, since the usual frequency range permits monitoring output from a homebrew transmitter across the 0.55-32 MHz range for harmonics, parasitics and spurious radiations. A hamband receiver is limited in this respect, since it permits monitoring only spurious signals which appear within the hamband range. On the other hand, the hamband receiver has definite advantages in on-the-air operation as far as frequency readout is concerned.

(2) Sensitivity. Receiver sensitivity is a measure of the amplitude of signal needed at the receiver input terminals to produce a given audio signal output, usually referenced to the noise level generated in the receiver during the amplification process. Sensitivity is measured either in terms of the INPUT SENSITIVITY in microvolts (i.e., "sensitivity of 1uv"), or in terms of SIGNAL-TO-NOISE-RATIO (i.e., 1uv input for a 10dB S/N). Sensitivities on the order of 2uv are entirely adequate for stateside QRP operation, while 0.5uv sensitivity will suffice for most DX signals. The latest solid-state receivers and transceivers usually fall into the 0.3uv for 10dB S/N sensitivity range. Actually, this is better than MINIMUM USABLE SENSITIVITY (**MUS**) as far as 160, 80 and 40 meters are concerned, and just slightly better than what is usable on 20, 15 and 10 meters. Atmospheric noise sets the limits of usable sensitivity up to about 18 MHz, while galactic noise sets the limits above 18 MHz. Manmade noise adds to the total noise power at the input terminals of a receiver. For example, at 7 MHz, atmospheric noise will generally provide something around 0.4-0.7uv across the 50-Ohm receiver input terminals, and any incoming signal that falls within that range will be buried in the noise. The amplitude of the input signal would have to be considerably higher than the noise input to produce a desired 10dB S/N. In other words, a 3uv sensitivity could do a good job in this case.

More recently, manufacturers have replaced the sensitivity specification with MINIMUM DISCERNIBLE SIGNAL (**MDS**), defined as the input signal power that will produce an audio output that is equal to the noise generated within the receiver. MDS is more commonly referred to as the NOISE FLOOR of the receiver, and is stated in terms of dBm, or decibels below one milliwatt input (i.e., -111dBm). Noise floors of -137dBm have been achieved in some of the most sensitive modern receivers. Generally, homebrew direct conversion receivers with no r.f. amplifier detector can be expected to exhibit a noise floor of about -100dBm, while designs such as the HW-8 which include front-end r.f. amplifiers measure out at around -110dBm. These correspond to signal inputs of 0.03uv (-137dBm), 2.3uv (-100dBm), and 0.7uv (-110dBm) across 50-Ohms. Ultimately, sensitivity is often a very subjective parameter in operation — excellent c.w. operators are often able to read signals buried 10dB or so below the noise level. A great number of QRP operators — including me — have worked a plethora of weak signals from each other using nothing more than homebrew direct conversion receivers with sensitivities of 2-3uv or worse, especially on the lower bands, where such sensitivities are more than actually usable. The bandwidth of the i.f. filter limits the noise floor figure: a 250 Hz bandwidth will provide a lower noise floor than a 2.5 KHz bandwidth. For example, a test report may state a -129dBm noise floor (MDS)

Fig. 2. Typical Selectivity Curves.

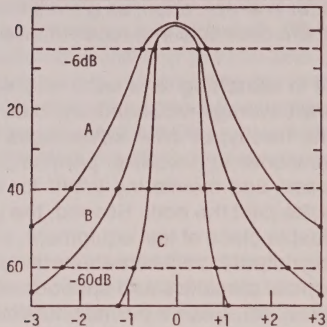
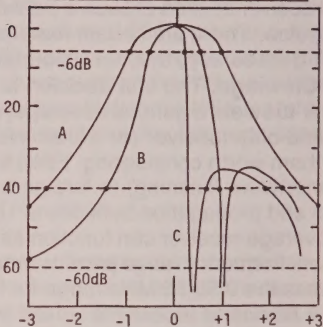


Fig. 3. Crystal Filter Curves.



for a 2.5 KHz bandwidth, while another unit may exhibit an MDS of -139dBm with 250 Hz bandwidth. The two receivers have roughly equal sensitivities.

(3) Selectivity. Selectivity is often more important than sensitivity on today's crowded bands with KW's putting out S9 + 40dB signals. Selectivity is a measure of a receiver's ability to reject unwanted off-frequency signals while amplifying desired on-frequency signals. Selectivity is determined by the nature of the filters found in the receiver front-end and in the i.f. amplifier. Front-end filtering is the determining factor with respect to rejection of signals across the r.f. spectrum, both near to and far removed from the frequency of operation. The major effect of poor front-end filtering is cross-modulation, where an unwanted signal distorts the desired signal in a variety of manners. Generally, older receivers used simple L/C tank circuits as front-end filters, and these were entirely adequate in the days when those receivers were designed. More recently, manufacturers have turned to more sophisticated front-end filters, using bandpass 2-and 3-pole networks. A great improvement in immunity to cross-modulation results from such filters. Usually, older receivers can be expected to perform adequately, and if a problem arises, construction of an add-on filter or a preselector will solve any problems. These items are relatively simple to construct. In many cases, adequate i.f. filtering covers front-end inadequacies.

(4) I.F. Filter Selectivity. The selectivity of a receiver with respect to separating signals within the i.f. passband, and from adjacent signals on nearby channels, is largely determined by the nature of the filter used in the i.f. amplifier circuit. Several types of filters appear in receivers and transceivers, including high-Q L/C, crystal-phasing, Q-multiplier, T-notch, mechanical, and bandpass crystal-lattice. I.f. filter response is a key specification for receiver performance, and is given in several interrelated parameters, including skirt selectivity, skirt response, and shape factor. Each of these is a numerical description of the selectivity curve of a filter which graphically depicts the filter's ability to attenuate signals removed a stated distance (frequency) from the filter center frequency. Fig. 2 provides a set of selectivity curves which illustrates the relationships between numerical and graphical descriptions. The vertical portion of each curve is often referred to as the "skirt," and curve C is said to exhibit a "steep skirt" while curve A exhibits a "broad skirt". The bandwidth is simply the range of frequencies falling between the skirts at some stated level of attenuation. At the -6dB points of the curves, A has a bandwidth of about 1.6 KHz, while B and C exhibit a bandwidth of about 1 KHz. At the -40dB points, A broadens to about 5 KHz and B to 2.8 KHz, while C is only 1.4 KHz. In practical terms, the three curves will exhibit a phenomenal difference in their ability to reject unwanted signals close to center-frequency. For example, suppose that a S9 + 20dB signal appears 1 KHz above or below center frequency, and the desired signal is at center-frequency, but 30dB

weaker than the other. Skirts A and B will attenuate the undesired signal only about 10dB, leaving it at an S9 + 10dB level. However, C will attenuate it about 60dB. Assuming that an S-unit represents a 6dB difference in signal strength, and the noise floor of the receiver is at 0dB, the undesired signal is 74dB above the noise floor ($9 \times 6\text{dB} = 54\text{dB}$, $54\text{dB} + 20\text{dB} = 74\text{dB}$), while the desired signal is 44dB above the noise. With 60dB attenuation, the undesired signal is lowered to the 14dB level resulting in a desired signal 30dB stronger. Quite a difference. The numerical description in specifications for a receiver could state the same relationships by comparing filter bandwidths at two attention points of the selectivity curve. For example, the first bandwidth is almost universally the -6dB point, while receiver manufacturers tailor the second bandwidth to place their product in the best possible light. Bandwidths stated at the -40dB point usually attempt to cover the fact that the skirts flare outward below the -40dB point, while those stated at -60dB are more trustworthy as an indication of the real selectivity of the receiver filter. Only the most intrepid manufacturer will dare publish a -120dB bandwidth specification (Hammarlund SP-600-JX21 for example). Rather than stating both bandwidths (-6dB, -60dB), a ratio of the two bandwidths is used instead and is termed the "shape factor", the ratio of the bandwidth measured at the -6dB point as compared to the bandwidth at the second point of the curve. For example, a typical specification reads: "SELECTIVITY — 2.4 KHz at 6dB down. Shape factor of 1.7 at 60dB down." The 60dB down bandwidth is the shape factor multiplied by the -6dB bandwidth; in this case $2.4 \text{ KHz} \times 1.7 (\text{shape factor}) = 4 \text{ KHz}$ bandwidth at -60dB points. Any shape factor of under 2 is very good. An ideal filter would exhibit a shape factor of 1:1, but the best that is found in modern receivers is about 1.6. The selectivity of the filter depends upon the type employed, and types vary with the design and age of the unit.

(a) Receivers of the 50's usually employed high-Q L/C tank circuits to achieve i.f. selectivity. The shape factor attainable with this is usually rather poor. For example, the Pierson-Holt KE-93 produced a shape factor of 2.3 with 14 tuned L/C tank circuits and was heralded as a highly selective mobile receiver at the time. In some cases, such as the SP-600, three L/C networks were employed for selectable bandwidths of 3-, 8- and 13 KHz for wide bandpass operating (a.m.) while three crystal filter bandwidths of 0.2, 0.5, and 1.3 KHz provided narrow bandpass filtering.

(b) A second method of achieving selectivity in older receivers was by means of a high-Q adjustable peak/notch filter known as the "Q-multiplier." Controls on the front panel allowed the operator to control the shape of the selectivity curve, as well as move either the filter notch or peak frequency to either attenuate or amplify a given signal falling in the filter passband. The Q-multiplier was included on many Hammarlund receivers and added greatly to their flexibility.

(c) The adjustable-phasing crystal filter provided the same function as the Q-multiplier, but used a crystal with its extremely high-Q to produce the selectivity curve. This type of filter is very useful in c.w. operation, since the bandwidth can be switched by means of the front-panel selectivity switch, while the depth and frequency of the filter notch or peak shifted by means of the phasing control. In Fig. 3, for example, the bandwidth at the -6dB points is shown for selectivity switch positions A-B-C to the left of the center frequency line. To the right, the effect of the phasing control is seen as the notch shift with respect to center frequency. Since only a single crystal is used in this type of filter, the ultimate depth of the notch is around 40-50dB; but in an operating situation, the ability to reject an unwanted signal by 40dB makes all the difference in the world. Theoretically, the notch depth is infinite, but in practical circuits, leakage limits it to the above range. Receivers which used the adjustable-phasing crystal filter generally permitted front-panel control of the beat frequency oscillator (b.f.o.) frequency, adding another element of flexibility to the selectivity of the unit. By moving the b.f.o. frequency above and

below the filter center frequency, the operator is able to capitalize even further upon the filter's discriminating capability. Personally, I prefer operating with a receiver using this type of filter/b.f.o. combination because I am able to do things that are not possible with fixed passband filters.

(d) The "T-notch" or "bridged-T" filter is basically a rejection filter. Front panel controls permit controlling both the frequency and the depth of the notch. Since this is a simple L/C network type, its usefulness is limited to receivers using low frequency i.f.'s (100, 450 KHz) and is not used in modern 5.5 MHz and 9 MHz i.f. systems. The same basic effects can be achieved using a tunable active audio filter, but it is an asset on an older receiver such as the RME-6900.

(e) Modern transceivers and receivers from the mid-60's onward generally employ fixed passband crystal-lattice filters with the fixed b.f.o. frequencies for lower and upper sidebands, and hence lack the flexibility of some of the older filters. However, much better shape factors are possible with the passband filter, since any number of crystals can be cascaded to drop the selectivity skirts closer to the vertical. The effectiveness of such a filter depends upon the number of crystals used, usually stated in terms of "poles" (i.e., 4-pole, 8-pole, 16-pole). The more poles, the better the filter usually, provided it is properly designed and terminated.

As noted earlier, s.s.b. transceivers since the mid-60's frequently employ a wide 2.1 KHz or 2.4 KHz passband filter in both s.s.b. generator and receiver i.f. circuits, since these units were designed primarily to appeal to the s.s.b. market. If a given transceiver includes only a single filter, it will be a wideband type and seriously impede the usefulness of the unit for c.w. operation, since 10-20 c.w. stations frequently will appear in the filter passband during crowded operating situations such as are found in a contest. Improving the usefulness of such a unit requires the addition of a narrower-passband filter for c.w. operation, and many manufacturers provide these as accessories. Another option that is more economical is the addition of an active audio filter PRIOR TO THE AGC CIRCUIT. An outboard c.w. filter plugged into the phone jack will not result in worthwhile improvement, since the AGC circuit responds to all signals reaching it through the passband of the i.f. filter. For example, suppose that the desired c.w. signal at 700 Hz from filter center frequency is at the S5 level, while another S9 + 10dB signal is 1600 Hz from center frequency. Both signals are within the 2.4 KHz passband of the filter, and the AGC circuit responds to the stronger of the two, depressing front-end and/or i.f. amplifier gain/s to produce the limit of audio output for which the AGC circuit has been designed. If that audio output limit has been designed to drop all signals to the level of an S8 input signal, then the gain of r.f. and/or i.f. amplifier/s will be depressed about 16dB to drop the S9 + 10dB signal to the S8 level. The AGC also depresses the S5 desired signal an equal amount, leaving it the equivalent of an S2 + signal. In short, the AGC circuit responds to the strongest signal in the passband, but depresses the amplitude of all signals in the passband by an equal amount. Insertion of an active audio filter as a means of narrowing the bandwidth of the unit, hence, must be at a point in the circuit PRIOR to the AGC circuit. The typical point is immediately following the product detector stage and prior to any stages of audio pre-amplification. Details on the addition of an MFJ CWF-2 4-pole audio filter to the Argonaut 505 are found in "Improving C.W. Selectivity in the Argonaut," CQ (January, 1977), and the approach is applicable to any other s.s.b. transceiver employing a single wide passband i.f. filter. More recently, TenTec and other manufacturers have offered active audio filters for c.w. operation as an accessory and have provided rear panel access to the proper pre-AGC insertion point. The performance of an s.s.b. transceiver with add-on active audio filter for c.w. operation is determined both by the skirts of the i.f. filter and the audio filter's response curve — the CWF-2 filter with its optional 4

stages of active filtering turns the Argonaut and its wideband filter into a single signal c.w. receiver; in fact, it will turn a DX contest band into a "no one's on" situation!

(f) The mechanical filter is an alternate to the more popular crystal filter and is found on some s.s.b. transceivers. Its function is essentially the same.

(5) **B.F.O. Control.** Older receivers frequently include a tunable b.f.o. so that the position of the b.f.o. injection signal can be located on the selectivity curve to suit the situation. When used in combination with crystal filter phasing and main frequency tuning, an incoming signal can be placed in either the peak or notch of the filter. Modern s.s.b. units use fixed-frequency b.f.o.'s.

(6) **Product Detector.** Pre-s.s.b. receivers used a simple diode detector to convert r.f. output from the i.f. amplifier into audio output. If s.s.b. operation is contemplated, a receiver employing a product detector circuit is preferable. A clue to whether an older receiver includes a product detector is given by the function switch — if it includes s.s.b. along with c.w. and a.m., it probably uses a product detector.

(7) **AGC Defeat.** Receivers from the pre-s.s.b. days had automatic gain control (AGC) circuits designed for a.m. reception, with slow attack/slow decay time-constants. This type of AGC is suitable for c.w. operation. However, units designed for s.s.b. reception usually employ a fast-attack/slow-decay AGC with no means of defeating the AGC except by backing off the r.f. gain. Many c.w. operators find the latter AGC time-delay annoying during operation with strong signals present.

(8) **Speaker/Power Supply.** It is always wise to check whether or not a prospective purchase includes the power supply and speaker. Most older receivers have an internal power supply, but no built-in speaker. Modern units generally lack both. Adding a speaker is a simple matter, but the power supply is a major task.

The above comments should be helpful for understanding receiver specifications given in ads or in Brand's **Ham Equipment Buyer's Guide**. It is wise to stick to top-of-the-line units as indicated by the new price in the context of the other receivers offered by a company. Of course, it goes without saying that the condition of the unit must be good-to-excellent. Query the seller about the unit's frequency stability which is usually a clue to the amount of component deterioration that has occurred. Likewise, facts about the last realignment, replacement of tubes,, and other servicing can give some indication of the care the unit has received. By careful shopping, a QRP station consisting of used receiver and transmitter or transceiver can be assembled for under \$300 and provide quality performance. In scanning the "yellow sheets" over the years, I've rarely encountered an issue which didn't provide a combination such as an SB-400 at \$150 and Drake 2A at \$125, or more economically, a DX-60B at \$65 and HQ-145C at under \$100. Older transceivers like the Hallicrafters SR-150 often can be had at around \$200 if that is the route chosen. As long as the circuitry is in good shape, a few scratches or dents on the box can save quite a bit of money — after all, no one wants a junky-looking rig — that is, except the guy who only is concerned with how well it works!

III. Operating the QRO Transmitter/Transceiver at QRP Levels.

Converting a high-power transmitter/transceiver to QRP operation is frequently possible without modification to the unit. In this section, we will examine various approaches which have been successful. Some means of measuring d.c. input power and r.f. output power and monitoring signal purity are necessary for putting a QRO unit into QRP service. Section IV below provides details about equipment that can be useful. Ultimately, a clean, spurious-radiation free and

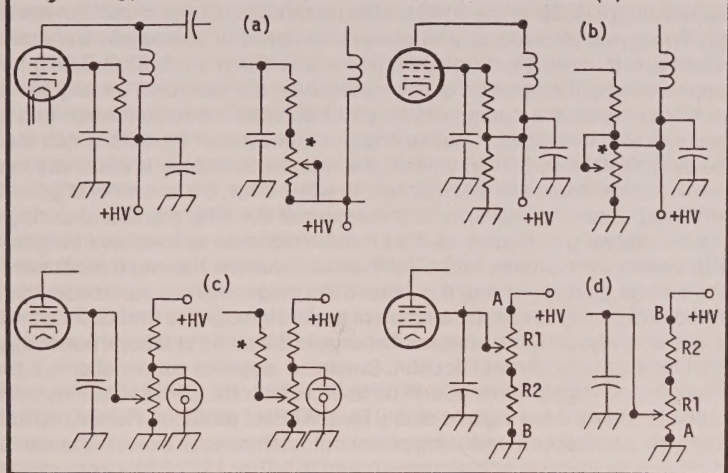
harmonic-free 5-watt signal is the objective in converting a QRO unit to QRP operation. To achieve this objective, several basic strategies can be employed in conjunction with standard signal monitoring procedures to insure that the unit is functioning properly at low power levels.

Once the unit has been tested at the full-output level and the interaction of its tuning controls noted, a preliminary test of QRP feasibility can be carried out simply by connecting the unit to a wattmeter, Breune in-line SWR wattmeter with 50-Ohms dummy load, or 50-Ohms dummy load in conjunction with a VTVM/DVM and r.f. probe. Many operators perform this preliminary test while the unit is connected to the antenna, but this is a wrong approach, as will be explained later. Depending upon the particular unit, power output can be lowered by means of the front-panel controls such as DRIVE, MIC. GAIN, AUDIO GAIN, or final amplifier LOAD. After tuning the unit for maximum output, slowly decrease output by means of the DRIVE or MIC. GAIN control while monitoring the decreasing output on the wattmeter or or VTVM. If the decrease in output occurs smoothly without any "jumps" or other intermittent irregularities, the lowest level of output that can be reached by means of the control can then be noted. This should be near the 5-10 watt level. As an added precaution, signal purity should be monitored according to procedures noted below (Section IV) before placing the unit on the air. In the event that this test proceeds smoothly, but the minimum attainable output exceeds the 5-watt QRP limit, output can be further decreased by detuning the final amplifier as noted below. If output cannot be dropped to the 5-watt level through the simple decrease in drive level and amplifier loading, a minor modification usually will do the trick. In the event that a marked jump or discontinuity occurs during the process of decreasing the r.f. output, refer to Section IV.2 below.

(1) Drive Control Adjustments. Several conventional circuit approaches have been used widely in transmitter and transceiver designs as a means of controlling the amount of drive power delivered to the final amplifier, and some manufacturers have come up with variations to suit their particular requirements. In the event that a given unit will not drop to the QRP level by adjustment of the drive control and amplifier loading, a check of the method used to control drive power in the unit will lead to a simple modification that achieves the 5-watt output objective. Generally, the drive control is usually found in the driver or final amplifier stages of tube transmitters or hybrid transistor-driver tube-final amplifier circuits. Solid-state transceivers may place the drive control in the audio amplifier (microphone circuit) or at some other point in the circuit. Let us consider tube circuits first.

(a) In tube transmitters, the amount of drive power delivered to the final amplifier is in part limited by the voltage applied to the screen-grid of the driver tube. The positive charge on the screen-grid regulates the signal-current flow from cathode to plate, and lowering the screen-grid voltage decreases the flow. Typically, the biasing circuit supplying the screen-grid voltage is designed to produce maximum power output. The biasing circuit can consist of three configurations, as seen in Fig.4. In Fig.4a, a simple series dropping resistor is inserted between the high voltage B+ lead and the screen-grid terminal; the screen current flowing through the resistor drops the high voltage B+ to the proper screen-grid bias voltage. In Fig.4b, a voltage divider circuit performs essentially the same function, but variations in screen current caused by changes in excitation to the tube are swamped by the divider, resulting in less fluctuation in the screen-grid voltage with fluctuations in excitation and loading. In Fig.4c, a regulator tube holds the voltage at the center of the voltage divider to a constant level (OA2 regulator — 150 volts) to eliminate changes in screen-grid voltage. The values of the dropping resistors in each of the configurations can be calculated by Ohms Law if maximum screen current and voltage ratings are known, and the supply voltage is known. Maximum screen currents at a screen voltage of 150 volts for several typical driver tubes are: 6AU6 — 7ma, 6BA6 — 4.2ma, 6CL6 — 7ma, and 12BY7 —

Fig. 4. Typical Screen-Grid Circuits and Modifications (*).



6ma. Values for these ratings can be found in the "Vacuum Tube Data" section of the **ARRL Handbook**. When making modifications to the screen-grid circuit, the only consideration is that these ratings are not exceeded; since the QRP operator's objective is to lower power, he'll go in the opposite direction, so no problem will occur.

When confronted with a unit which includes a drive control that won't drop output power to the QRP level, or a unit which has no drive control, several simple modifications to the screen circuit of the driver stage will do the trick. **BEFORE ANY MODIFICATIONS ARE ATTEMPTED, THE UNIT MUST BE TURNED OFF AND THE POWER SUPPLY FILTER CAPACITORS DISCHARGED.** The usual practice (although Underwriter's Labs wouldn't approve) is to turn the power supply off and "crowbar" the high voltage B+ lead by shorting it to ground with a screwdriver. Fig.4a shows a typical circuit which lacks a front-panel drive control. In this case, the unit can be modified for QRP operation by inserting a series potentiometer into the screen-grid circuit. The potentiometer, marked by the asterisk, should be about twice the resistance of the screen-grid resistor. In Fig.4b, the fixed voltage divider can be modified in similar fashion. A potentiometer of roughly equal value can be substituted for the original resistor at the ground end of the divider. In the case of the drive control which fails to lower power all the way, the simple expedient of adding a series dropping resistor between the drive control potentiometer and the screen-grid terminal will suffice, as seen in Fig.4c. Depending upon the unit being modified, other approaches may be more suitable. For example, the Heath HW-16 employs a screen bias circuit similar to Fig.4c, except that no regulator tube is included, and the drive control adjusts the screen voltage of the final amplifier stage instead of a driver stage (see Fig.4d). The strategy in this unit consists simply of reversing the connections at A and B, and permits operation of the unit in the 250mw — 4.5 watts output range. Also, some circuits may be encountered with no screen voltage dropping circuit; instead, the screen voltage is taken from a regulator tube connected to a separate power supply output designed to provide the correct screen voltage. The series potentiometer strategy can be applied in such a case. Finally, the drive control in s.s.b. tube transmitters may not be located in the driver amplifier stage. For example, the DRIVE LEVEL control in the Heath HX-20 varies the bias on the grid of the

i.f. amplifier tube. However, this unit can be operated down to 250mw or so merely by substituting a 2E26 for the 6146 and no modification to the circuit is necessary.

(b) Two types of drive control are encountered in solid-state transmitters/transceivers. In units which include only a MIC GAIN (or AUDIO GAIN) for the microphone amplifier section of the transceiver, the control is usually switched internally between the audio section and balanced modulator when changing from s.s.b. to c.w. modes. Cost-savings — Buncombe! In units which include both a MIC GAIN and DRIVE control, the internal switching is eliminated and a separate control is used for each circuit. In either case, a c.w. carrier is generated by shifting the carrier oscillator to the center of the filter passband during c.w. operation, allowing it to pass as the r.f. drive signal to subsequent stages. The DRIVE control (or switched MIC GAIN) unbalances the balanced modulator and controls stage gain by varying d.c. bias to the stage. In the s.s.b. mode, the MIC GAIN control simply varies the amount of audio signal fed to the balanced modulator, and consequently the amount of energy in the audio sideband passed by the i.f. filter for subsequent amplification. Since the amplifier stages of an s.s.b. unit are designed for highly linear operation to avoid distortion products, they will usually accommodate drive signals of any level without problem. Hence, no trouble should be encountered in reducing power output from such a unit to the minimum level attainable through adjustment of the DRIVE or MIC GAIN controls. Many QRP operators have used QRO solid-state transceivers by Kenwood, TenTec, Yaesu, Heath and others in this manner. For one, Margaret H. Williams (K14W) used a TenTec Triton IV at less than one-watt output in qualifying for DXCC-Milliwatt Trophy #4. In most cases, the QRO transceivers are operated at QRP power levels with full B+ voltage applied to the driver-final amplifier stages. This is a highly inefficient approach and can cause problems, which may show up during the power reduction test outlined earlier. It is advisable to lower the B+ on the driver-final amplifier stages when operating at QRP output levels, as will be explained below (see Fig. 8-10 and discussion).

(2) Final Amplifier Adjustments. A second strategy that can be used to implement drive control adjustments in lowering output power from a QRO unit involves reducing final amplifier loading to a minimum. This strategy is possible only in units using some form of tunable output matching network in the plate circuit of the final amplifier. Typically, a PI-network or L/C tank circuit is employed. Almost all tube-type rigs fall into this category, as well as most hybrid rigs utilizing tube driver-final amplifiers. More recent solid-state units are broadband designs employing fix-tuned bandpass filters for matching final amplifier to antenna, and these are not adjustable. Tuning the final for minimum r.f. output is simply a matter of reversing the usual tuning process aimed at obtaining maximum output. The PA TUNING and LOAD controls (or equivalent) are used in the process. Normally, plate current is monitored while the PA TUNING control is adjusted for the greatest dip in plate current. Next, the LOAD control is adjusted to increase the plate current, and the process repeated until maximum plate current is achieved. In reducing output, the LOAD control is adjusted to cause an even greater dip in plate current, and the process repeated until plate current is at its minimum. In the event that the unit has a DRIVE control and it has been backed off to the minimum drive level, the resulting plate current may be so small as to provide little or no dip on the plate current meter. In this case, increase the drive level until the plate current dip can be detected and correlated with r.f. output on a wattmeter. Once the proper adjustment of the final amplifier controls is established, the DRIVE control can then be used to decrease output to the desired level.

With respect to units that include a PA TUNING but no equivalent of a LOAD control, the foregoing approach will not be applicable without some modification to the unit. If only a single tuning control for the final amplifier appears on the unit, it is likely that the manufacturer has gained a savings on components costs by

substituting bandswitched mica capacitors for a more expensive air-variable capacitor, as seen in Fig.5. Two strategies can be applied. First, locate the bandswitch wafer on which the micas are mounted, and disconnect the lead from the antenna side of the PI-network as seen in Fig.5a, where the circled "X" shows the break-point. Next, install an air-variable capacitor across the antenna end of the PI-network as seen in Fig.5b. The capacitor can be a standard "APC" type, since the r.f. voltages encountered at QRP levels require little air-gap clearance between capacitor plates. The variable can be mounted where convenient — either on the front panel if space is available, or on the rear panel, and used as noted above in adjusting for low power output. Second, a bank of mica trimmers (Elemenco-Arco types — see "Parts Sources", Chapter 5) can be substituted for the fixed micas if space is available on or near the bandswitch. Mica trimmers are rated at breakdown voltages of over 100 volts, and hence no problems should be encountered with r.f. voltages developed at QRP power levels. Once the trimmers are in place, they are adjusted for desired r.f. output on each band. The circuit is shown in Fig.5c. If this strategy is followed, **CAUTION MUST BE EXERCISED DURING ADJUSTMENT OF THE TRIMMERS TO AVOID CONTACT WITH THE HIGH VOLTAGE POINTS IN THE CIRCUIT.** Severe shock and possibly fatal consequences can result from contact! This writer has been zapped by 1200 volts on a number of occasions because of impatience — these were very memorable experiences akin to being hit with a ballbat, but not the kind to be repeated! These two modifications will in part be determined by the physical space that is available in the unit. The variable capacitor approach provides maximum flexibility and space can usually be found for mounting it; the trimmer approach can turn out to be a hassle.

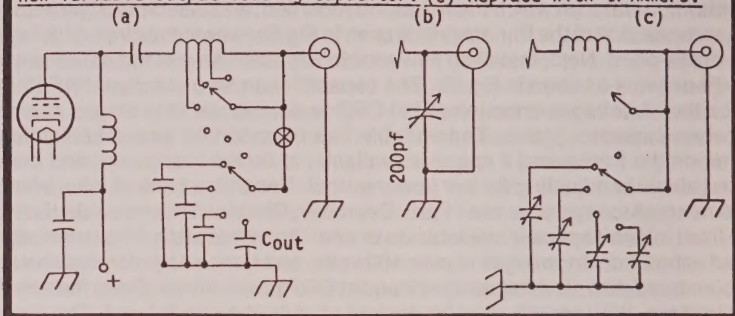
(3) Substitute Final Tube; By-Pass Final. A third strategy involves a minimal modification. A lower output range can be obtained simply by substituting a "little brother" tube for the original final amplifier tube. The popular 6146 (90w) is matched by the 2E26 (40w) and both tubes have identical socket connections. Screen-grid dissipation ratings are similar in both, eliminating any need for modification in that area. In the event that the rig employs a TV sweep tube in the final amplifier, a local TV repairman may be able to suggest a lower power substitute with the same socket connections. Otherwise, the ambitious individual can rewire the final amplifier tube socket to accommodate a lower power tube. But this is hardly worth the effort, since simply by-passing the final amplifier stage is easier and will produce the desired results. A source of tubes either for replacement or substitution is: Unity Electronics, Dept Q, PO Box 213, Elizabeth, NJ 07206. A free catalogue is available upon request.

Many operators have converted their favorite tube rigs to QRP operation by removing the final amplifier stage from the circuit. The simplest approach is to remove the final amplifier tube from its socket, and connect a jumper wire between the PI-network input and driver stage output, as shown in Fig.6. In this case, the high voltage B+ to the final amplifier must be isolated from the driver stage and PI-network. Fig.6 shows break points with the circled "X". Some means of monitoring driver stage tuning is necessary — the milliammeter used to monitor final plate tuning can be rewired into the B+ lead of the driver stage. Or a new 100ma meter can be added to the driver stage to provide readout of plate current at QRP levels.

(4) Driver-Final High Voltage/Vcc Adjustments. A fourth strategy of lowering power output from a QRO unit involves a minor modification. This strategy consists of decreasing the high voltage on the plate of the final amplifier tube/s, or decreasing the B+ (Vcc) on the collector/s of the driver-final stages in a solid-state unit.

(a) As noted earlier, most older tube-type rigs employ a PI-network in the final amplifier for output matching, and typically, the adjustable network is able to

Fig. 5. (a) Original, fixed output capacitors, break at X for (b), new variable output loading capacitor. (c) Replace with trimmers.



match a wide range of load impedances and plate impedances. Hence, it is possible to operate such amplifiers with lower voltages than those for which they were designed. As noted in Chapter 1, one QRP'er used an ARC-5 transmitter in a mobile installation and operated the plates and screens of the 1625 (a 12 volt 807) amplifier tubes directly from the auto battery, developing about 40mw output. Modification for lower plate/screen voltage requires rewiring the power supply hookup of a given unit. Typical tube rig power supplies provide separate transformer windings and rectifier-filter circuits for the low voltage (200-300vdc) output to pre-final stages and for the high voltage (600-1200vdc) output to the final amplifier. This strategy involves disconnecting the high voltage supply lead from the final amplifier circuit, and connecting the low voltage supply in its place. In units with self-contained power supplies, the modification consists of locating the high voltage output lead from the power supply circuit and disconnecting it from the final amplifier circuit. The disconnected high voltage lead should be wrapped with several layers of electrical tape and then secured in order to avoid shorting. Next, the power supply lead furnishing the low voltage is located in the supply circuit, and a jumper connected from it to where the high voltage lead previously was connected to the final amplifier. It is wise to provide r.f. isolation by means of a 2.5mh r.f. choke and bypass capacitor, as shown in Fig. 7. If the unit uses an external power supply, the switching of high and low voltage leads can be performed at the power supply output socket (see Fig. 7). In circuits featuring a regulated 150v screen supply, the only limitation is that the plate low voltage supply should provide in excess of 150 volts. In typical circuits where the screen voltage is obtained through the series dropping resistor or voltage divider, this limitation will not exist. Once the plate circuit is modified in this manner, the drive control should be usable throughout the QRP power range.

Fig. 6. Bypass Final Amplifier. Break Leads at X.

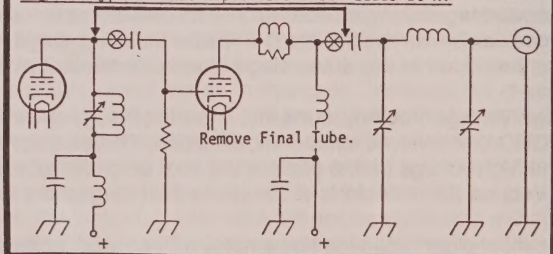
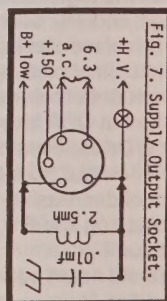


Fig. 7. Supply Output Socket.



Obviously, a cost-savings can be realized when purchasing an older transmitter or transceiver lacking an integral power supply. The seller will undoubtedly knock the price down if the lack of power supply is stressed as an almost insurmountable obstacle to placing any operational value on the unit. In this case, a supply providing the required voltages and a high voltage output in the 250-400 volt range can be homebrewed very economically. Power supply construction for tube rigs is non-critical, and B + voltages may vary considerably without affecting proper operation of the unit. The **ARRL Handbook** provides all details needed for construction of a supply.

(b) The same type of savings can be realized when purchasing a solid-state transmitter or transceiver lacking a power supply, but there are more important reasons for operating such units at decreased B + levels during QRP operation. While nearly all solid-state units can be operated at the QRP level simply by reducing the drive, two undesirable effects can result. First, of course, this results in highly inefficient operation. A unit designed for operation at the 100 watt output level, when operated at 5 watts output, will exhibit efficiencies on the order of 10% or lower. Operating at such inefficiency is, of course, the operator's prerogative. Beyond that, operating in this manner without lowering the B + to the driver-final stages is an invitation to problems in the form of harmonics and other signal impurities, especially in the c.w. mode. This is due to the method used to generate the c.w. carrier and the broadband design of such units.

As noted earlier, in the c.w. mode, most c.w./s.s.b. transceivers generate the r.f. carrier by shifting the carrier oscillator into the center of the filter passband and unbalancing the balanced modulator so that it functions as an amplifier. Typically, the carrier oscillator is an untuned stage, so that it includes no means of harmonic suppression. At best, the balanced modulator will include a single interstage coupling transformer which provides perhaps 20-30dB suppression of harmonic energy. Unbalancing the stage is likely to have the effect of enhancing harmonics generated as a matter of course in the carrier oscillator. Finally, while the typical crystal filter, when terminated properly, will present a resistive impedance to the balanced modulator stage at frequencies in and near its passband frequency, at frequencies far removed (as in the case of a harmonic) it presents a highly reactive impedance which can interact with the filter input transformer to actually enhance harmonics and out-of-band signals. Subsequent stages are designed for highly linear operation and are usually broadbanded, with perhaps another mixer stage included. In short, a rather complex set of harmonics and mixing products can result prior to the driver-final stages which will be amplified linearly by those stages.

The broadband driver-final stages are followed by a low-pass or bandpass filter designed to attenuate undesired signals to acceptable levels. However, while the filter elements are inherently linear and respond to all signal levels identically, this response depends also upon a proper matching of the filter to the final amplifier collector/s. A conventional or a transmission-line step-up transformer is used to transform the collector load impedance of the final transistors to the input impedance of the filter. Both exhibit fixed impedance transformation ratios designed for the maximum output power level of the unit. When the output power is dropped below that level, the collector load impedance rises accordingly, while the input impedance of the filter remains constant. For example, consider the rise in collector load impedance with decrease in output power in a solid-state amplifier designed for an output of 100 watts at a V_{cc} of 13.6 volts (see Fig. 8a). At the full rated output of 100 watts, collector load impedance is 0.942-Ohms. As power output decreases, collector load impedance rises until, at 5 watts output, it is 18.5-Ohms — 20 times higher. Clearly, a mismatch situation exists between collector load impedance and filter input impedance which will seriously degrade filter performance. It is safe to predict that any harmonics in the drive signal to the driver-

Fig. 8. (a) Collector Load Impedance at Reduced Power Outputs, and (b), Reduced V_{CC} to Maintain Correct Output Network Match.

(a)		(b)					
P_o (watts)	Z_c (Ohms)	$Z_c = .942$			$Z_c = 1.84$		$Z_c = 3.69$
		P_o	V_{CC}	I_{ce}	V_{CC}	I_{ce}	
100	.942	10	4.29	4.65	6.06	3.3	8.6
50	1.84	5	3.03	3.3	4.28	2.43	6.06
25	3.96	3	2.35	2.54	3.32	1.8	4.69
10	18.5	1	1.35	1.47	1.92	1.04	2.71
							0.74

(Note: values of (b) assume 50% collector efficiency. I_{ce} in amperes.)
 Formulae: $Z_c = V_{CC}^2 / 2P_o$; $V_{CC} = \sqrt{2P_o Z_c}$; $I_{ce} = .5(2P_o / V_{CC})$.

final amplifier stages will find their way to the antenna without significant attenuation, and if the antenna is mismatched to the output of the filter, the harmonics may even be enhanced. This situation is an invitation to self-oscillation also. In short, it is advisable to lower the B + (V_{CC}) to the collectors of the driver-final stages in a solid-state unit when operating at the QRP level.

The procedure for maintaining the correct match between collector load impedance and filter input impedance at QRP levels is simple. A combination of collector B + (V_{CC}) and output power (P_o) can be selected to approximate the collector load impedance for which the filter was originally designed at full output power. Assuming a typical 50% efficiency figure for the final amplifier, the collector load impedance at the maximum output of 100 watts (input 200 watts) can be seen in Fig.8a as 0.94-Ohms. In order to obtain that load impedance at 5 watts output, again assuming 50% efficiency, the correct V_{CC} can be calculated by formulae shown in Fig.8. Fig.8b tabulates several combinations of output power, V_{CC} and collector current (I_{ce}) for three collector load impedances of $Z_c = 0.942$ -, 1.84- and 3.69-Ohms. For correct match at 5 watts output with $Z_c = 0.942$ -Ohms, a $V_{CC} = 3.03v$ at an $I_{ce} = 3.3amps$ will work. The filter will be completely effective in suppressing any undesired signals generated earlier in the unit and amplified by the driver-final stages. Standard design practice is to make a 2:1 mismatch tolerable between final and filter input, so that a higher value of Z_c can be used to produce more reasonable d.c. supply current requirements. These are shown in the $Z_c = 1.84$ - and 3.69-Ohms columns of Fig.8b. Hence a considerable cost-savings can be realized when purchasing a unit without the power supply, since a d.c. supply capable of under-five volts at 4 amps can be homebrewed quite economically.

With respect to possible problems in the s.s.b. mode, less difficulty with harmonics will be encountered, since the balanced modulator is operating as a balanced modulator at full power. The difficulty that is likely involves an increase in noise output from earlier stages, coupled with degradation of the intermodulation distortion ratio in later stages. With the MIC GAIN control turned back, less audio signal reaches the balanced modulator, and lowers the signal-to-noise ratio in the output from that stage. Each subsequent stage contributes its noise. Typical driver-final amplifier stages are operated in Class AB and are biased for best IMD performance at rated maximum output. When output drops below that level, the IMD ratio degrades increasingly in proportion to the decrease in output from rated maximum power level. In theory, all this suggests that a QRO unit operated at QRP levels in the s.s.b. mode should be operated with lowered V_{CC} , but in practice, no one may notice any distortion or noise on the voice signal.

Modification of a solid state unit for use with lower V_{CC} on the driver-final stages is not difficult. The modification consists simply of separating the B + leads to the driver-final stages from the B + leads to the remainder of the unit, and providing a separate input jack or terminal for each. The driver-final is then connected to a

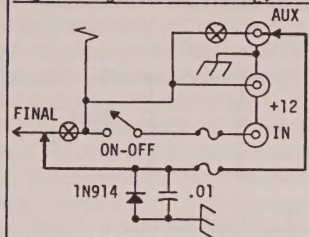
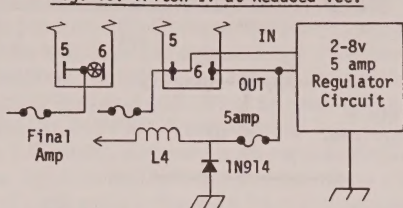
Fig. 9. Argonaut Mod for $Z_c, < 1w.$ 

Fig. 10. Triton IV at Reduced Vcc.



new low voltage power supply designed to provide the correct combination of B + and collector current, while the original 12-13.6 volt supply continues to power the remainder of the unit. Two examples will suffice.

First, many operators use the Argonaut at reduced power outputs as in G4BUE's milliwatt experiments noted in an earlier chapter. In the case of the Argonaut 509 and 515, a "+ 12v IN" jack and a "+ 12v AUXILIARY" jack are wired in parallel and mounted on the rear panel, as seen in Fig.9. Prior to making the modification, the correct combinations of Vcc and Ice at various reduced output power levels can be calculated from the formulae of Fig.8. It will be found that the power supply current requirements will be considerably lower than seen in Fig.8b, since the Argonaut is being dropped from the 3-5 watt output range down into the milliwatt range. Hence, the same power supply used originally will provide the current needed, although an extra power supply can be homebrewed to permit separate metering of voltage and current to the driver-final board of the Argonaut. As seen in Fig.9, the original connection between the auxiliary phono jack and the "+ 12v IN" jack is broken (circled "X") and the B + lead from the driver-final p.c. board connected to the "+ 12v AUX" jack through a fused circuit identical to the original one. Note in Fig.9 that the ON-OFF switch applies B + to the entire Argonaut; once this modification is completed, a separate switch is required for switching B + to the driver-final on and off. It is not shown in Fig.9, since it will be located at the power supply providing the low voltage to the driver-final p.c. board. If the original power supply is to be used to provide the lowered Vcc, a variable output three-terminal IC regulator can be added to it, with its 2-8v output connected to the driver-final p.c. board phono plug (+ 12v AUX) (see Fig. 10). Chapter 5 provides power supply design notes that can be used.

Second, the Triton IV mates with its power supply unit via a six-terminal jack on the rear panel; terminals 5-6 are soldered together and B + for the entire unit is taken from them, as shown in Fig.10. Since the original power supply easily provides required current for low power operation, the best strategy is to homebrew a 2-8 volts, 5 amps regulator and connect it as shown in Fig.10. + 13.6vdc is taken from terminal 5 for the input of the regulator, and regulator output connected to terminal 6. The original fused circuit consisting of L4, the 1N914 diode and 5 amps fuse is duplicated in the new driver-final lead from terminal 6. The discussion of power supply design procedures in Chapter 5 can be consulted in regard to selection of an IC regulator and heatsink requirements. In regard to the Triton IV, the Vcc/Ice combinations of Fig.8b can be applied directly in this modification.

In most recent solid-state driver-final circuits, d.c. bias to establish Class AB operating conditions is taken from a source other than the B + connection to the collectors of the driver and final transistors. The above modifications assume that this is the case. A check of the circuit schematic will serve to verify whether this is true of a given unit. If so, the modifications can be performed and the unit put into operation. Final amplifier standing current will remain the same as in operation with full Vcc, insuring linearity. However, if a given unit takes the d.c. bias for the driver-final stages from the B + lead to the driver-final p.c. board, further modifi-

Fig. 11. Symmetrical Resistive R.F. Attenuators and Values.

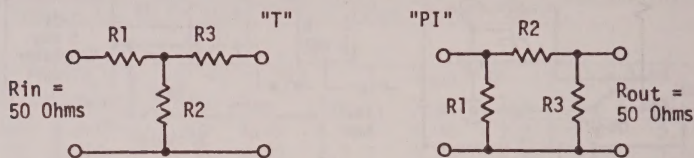


TABLE of Design Values for "PI" and "T" Attenuators.

dB	Po/Pin	"PI"		"T"	
		R1,R3	R2	R1,R3	R2
2	.631	436	12	5.7	215
3	.501	290	18	9	132
4	.398	220	24	11	105
5	.316	180	30	14	82
6	.251	150	38	17	67
10	.100	96	70	26	35
20	.010	63	220	41	10
30	.001	54	790	47	3.2
40	.0001	51	2500	49	1.0

Formulae: $v_{in} = \sqrt{P_{in} R_{in}}$; $P_o = P_{in}(P_o/P_{in})$; $v_o = \sqrt{P_o R_L}$;

$$v_{R2} = v_{in} - v_o; P_{R1} = (v_{in})^2 / R1; P_{R3} = (v_o)^2 / R3.$$

cation is required. The objective is to reconnect the d.c. bias lead to some point in the circuit where the full 12-13.6 supply voltage is available. Otherwise, the d.c. bias circuit will be supplied from the new low voltage supply and the driver-final will be improperly biased.

(5) Resistive Attenuator in Output. A fifth strategy applies in cases where the minimum output obtainable with drive reductions is up to 3 times the 5-watt QRP level, or in cases where the five-watt level can be reached but with distortion in the s.s.b. mode or spurious signals in the c.w. mode. This strategy consists of inserting a resistive attenuator between transceiver output and antenna and dissipating the excess power as heat. Some method of removing the attenuator from the line during receive periods is necessary — if left in the antenna lead to the transceiver or receiver, incoming signals will be attenuated accordingly. However, one advantage of this approach, although it decreases efficiency, is that the attenuator presents a resistive load to the amplifier output network. Antenna mismatch that could otherwise exceed SWR limits is partially swamped in proportion to the attenuation ratio and the number of sections included in the attenuator.

PI- and T-section attenuators are easily constructed using standard 1- or 2-watt carbon composition resistors (the regular brown resistor with color coding). Attenuator design values are shown in Fig. 11 for several power reduction ratios. The advisability of designing an attenuator with two sections can be shown by considering the power dissipation requirements for each resistor in an attenuator for lowering power from 20 watts to 5 watts. This corresponds to an attenuation of 6dB, or ratio of input to output power of 0.25. The reduction ratio is given by: $\text{dB} = 10\log(P_o/P_{in})$. The second formula in Fig. 11 is for output power from the first section when the reduction ratio is arbitrarily selected and used for the (P_o/P_{in}) term. As seen in Fig. 11, the resistor values for a 6dB reduction are $R1 = 150\text{-Ohms}$, and $R2 = 39\text{-Ohms}$. The attenuator presents a 50-Ohms load to the transmitter, and 20 watts across 50-Ohms will develop 31.6 volts r.m.s. across $R1$. This represents an $R1$ dissipation requirement of 6.65 watts. At least

three 2-watt resistors in parallel would be necessary for dissipating 6.65 watts. Finding standard value resistors to produce 150-Ohms with three in parallel can be a hassle (see **ARRL Handbook** for formulae and calculations). However, if the attenuator is designed with two sections, simplification results. By splitting the total 6dB reduction into two sections of 2dB and 4dB, R1 of the lead 2dB section will have to dissipate only 2.32 watts ($31.6\text{V}^2/430$). A single 2-watt resistor can be used. R2 dissipation figures out to 3.52 watts, requiring a pair of 2-watt resistors, and R3 dissipation = 1.86 watts. Input to the 4dB second section is 25 volts r.m.s., representing a dissipation of 2.86 watts in the lead R1 of the second section. Again, a pair of 2-watt resistors suffices for R1, and single 2-watt resistors for R2 and R3. With respect to selecting resistors for use in attenuators, the design values shown in Fig.11 can be obtained by paralleling standard value components. For example, since R1 (430-Ohms) requires a pair of resistors for the dissipation involved, a pair of 2-watt, 820-Ohm resistors would produce a parallel resistance of 410-Ohms, close enough for this application. A second approach is to "file up" a standard carbon composition resistor to the correct value. For example, 63-Ohms is not a standard value. A 56-Ohms resistor (standard value) can be filed up to 63-Ohms by filing a wedge into the center of the component. A triangular file (or edge of a flat file held at an angle) is placed perpendicular to the body of the resistor at the center of the resistor. Vigorous filing will eventually bare the carbon core (looks like the lead in a lead pencil). At that point, a VTVM can be connected across the resistor to monitor actual resistance. Filing proceeds cautiously, taking care not to place too much pressure on the resistor, which is best held flat against the index finger. As the carbon core is filed away, the resistance will begin to rise until the desired value results.

Construction of an attenuator is straight-forward. A minibox or homebrew p.c. board enclosure is fitted with coax or phono jack receptacles at both ends, depending upon the type of coax and connectors used, and then the enclosure is divided into two compartments (for two section attenuator) by mounting a shield midway between the ends of the box. A small hole is drilled in the center of the shield to permit passage of the lead connecting the two sections of the attenuator. The resistors are then soldered in place, with the ground clips of the coax or phono receptacles serving as grounding points. Attenuator construction is more economical (and sometimes quicker) if the walls and top/bottom are cut from double-clad p.c. board stock and then soldered together to form a box. In this approach, leave "eaves" outside the walls so that a solder bead can be run along the entire junction (see Fig.34). Spot-soldering at various points along the inside wall junctions will establish ground continuity. Once an attenuator is completed, the SWR it presents can be checked by hooking up the transmitter to a 50-Ohms dummy load through the attenuator and SWR bridge. If the above-mentioned method of paralleling standard value resistors is used, resulting departures from exact design values should result in no more than a 1.3:1 SWR, quite acceptable. An attenuator with several sections of differing reduction ratios which can be switched to provide several levels of attenuation is a valuable item to have around the shack.

IV. Monitoring Signal Purity

The conscientious operator routinely monitors his output signal to insure that his transmitter is functioning properly and generating a clean signal. Signal impurities are undesirable because they can cause interference to other operators and radio services, and further, they usually indicate some malfunction in the transmitter circuit. In the context of the present discussion regarding operating commercially produced QRO transmitters or transceivers at QRP power levels, extensive trouble-shooting should not be necessary, assuming that the unit was functioning

properly at full output. The manual for the unit will usually provide hints for trouble-shooting. The same does not hold true for homebrew transmitters, where more extensive checks for signal purity are necessary as part of adjustment and debugging procedures. In general, the objective of signal monitoring is to verify that the transmitter is not producing undesired signals in the form of harmonics or mixing products either on c.w. or s.s.b., or spurious sidebands on s.s.b. In checking signal purity, it cannot be assumed that if a given unit is clean on one band, it will be clean on all bands. Each band must be checked individually before putting the unit into operation on the air. For most situations, simple test equipment is adequate. A VTVM/FETVM/DVM equipped with a properly calibrated r.f. probe provides both d.c. and r.f. measurements capability (See comments in Chapter 5 & 8). A calibrated wattmeter or in-line Breune SWR wattmeter will permit measurement of r.f. output power as well. Several other devices are useful in this process. A standard TV is a quite sensitive detector of unwanted signals (v.h.f. and u.h.f. harmonics and self-oscillation parasites) from about 50 MHz upward. Likewise, FM receivers — “walk-man” types or others — provide a means of monitoring the 88-108 MHz FM band, as well as the spectrum around 10.7 MHz, the usual i.f. frequency used by these units. A general coverage receiver permits monitoring signal purity across its frequency range. Each of above units is useful for monitoring some dimension of transmitter performance. Of course, an oscilloscope (30 MHz bandwidth) will do it all and will even visually display the signal waveform, but newcomers usually have to wait before acquiring one (see Chapter 5, Sec. II.11).

(1) Preliminary Checks. As outlined in the previous section, the preliminary power output reduction test using the drive control in the c.w. mode will provide indication of the minimum attainable output from the unit, and more importantly, whether the unit develops indications of a problem at some point in the power range as evidenced by an irregularity of “jump” during the power reduction test. If the decrease is smooth and no jumps encountered, the second step is to repeat the test with the unit connected to an antenna through an SWR bridge capable of producing full-scale deflection at a few watts output.

With the SWR (QRP) bridge in the REFLECTED position, output power is reduced by means of the drive control to its minimum level. If an irregularity in the decrease of reflected power occurs, a problem exists even though it did not become apparent when the unit was hooked to a 50-Ohms dummy load. Since the dummy load presents a purely resistive impedance across the h.f. spectrum, it absorbs r.f. energy without sensitivity to frequency. However, an antenna presents a complex load impedance consisting of a resistive and a reactive component, and this complex load impedance varies with frequency. It becomes increasingly reactive as the signal is moved away from the antenna's resonant frequency. Hence, if harmonics or other out-of-band signals are fed to the antenna through the SWR bridge, these signals will encounter a highly reactive load, be reflected back down the transmission line and detected as reflected power. Thus, if the reflected power decrease jumps at some point during the power reduction test, the rig undoubtedly is generating undesired signal output at that point in the power range. If the reflected power drops back to the original SWR in the range below the problem point, it is likely that the unit's internal problem corrects itself below the problem point and the unit is clean except where the jump occurs and the unit is usable. (Argonaut 509/515 users can get an example of the jump by backing off the DRIVE control on 10 meters.) Further monitoring of the signal at the problem point will provide clues as to the nature of the signal, as will be noted below.

Once the test in the c.w. mode is completed, the s.s.b. mode can be checked. This test requires a separate receiver (if a transceiver is being tested), or if one is not available, an on-the-air check can be made by a local ham. The major concern

in the s.s.b. mode is distortion and spurious sidebands. The procedures for checking these involves two steps: (1) monitoring the quality of the s.s.b. signal for voice clarity, crispness, and lack of fuzziness or scratchiness; and (2), checking the spectrum about 10 KHz above and below the signal frequency for the presence of spurious sidebands, which usually sound like scratchy spikes occurring only at voice peaks. If a separate receiver is available, it must be adjusted properly to permit valid results.

Receiver operating conditions are aimed at minimizing stray r.f. field pickup and overloading. Sensitive receivers are able to detect signals emanating from within the transmitter shield enclosure, even though those signals do not appear in the unit's output after passing through the output filter network. To eliminate this r.f. pickup, locate the receiver as far from the transmitter as possible. Receiver input is coupled to transmitter output through an appropriate length of coax terminated in a one-or-two turn loop of hookup wire. This pickup loop should be positioned inside the dummy load or SWR meter enclosure so as to respond only to signal content in the filtered r.f. output from the transmitter. In the event that the receiver overloads from the signal sensed by the pickup loop, and it is not possible to reduce receiver r.f. gain to a usable level, the insertion of an attenuator in the line between pickup loop and receiver should solve the problem. It is wise to construct a switchable 40dB attenuator during free time so as to have it around the shack for a multitude of purposes. The total 40dB attenuation is divided into four, five or six steps, with each wired for switching in and out of the total 40dB. Values shown in Fig. 11 can be followed. If an attenuator is not available, one can be quickly assembled on a piece of perf-board or p.c. board stock with isolated pads scratched into the copper foil. Once the resistors and connectors are in place (or coax leads soldered directly to the input and output foil pads), the hay-wired unit is then wrapped with a layer of electrical tape, followed by a wrapping of kitchen aluminum foil which is grounded to the coax shield braids, and completed with another wrapping of electrical tape. The attenuator should be able to drop the input signal to within 20dB or so of the receiver's noise floor via the r.f. gain control adjustment. This indicates that proper r.f. isolation between transmitter and receiver has been obtained and valid monitoring is possible.

Once the receiver is operating properly, the s.s.b. signal is monitored on-frequency for the characteristics mentioned earlier. Since it is necessary to speak into the microphone during tests, headphones should be used to monitor the signal. R.f. gain is adjusted for an S7-S9 S-meter reading on peaks. Next, the receiver is slowly tuned away from the signal frequency (above or below, depending on which sideband is used) while monitoring for distortion and scratchiness. Once the outer edge of the filter passband is passed (3-4 KHz off center frequency), the sidebands should drop off very markedly, and the receiver r.f. gain can be increased to continue to monitor voice peaks. At about 8 KHz off frequency, sideband peaks should be detectable only with full r.f. gain. A relative judgment of spurious sideband levels can be made by comparing the setting of the r.f. gain needed to detect them 8 KHz off-frequency with the setting of the r.f. gain needed when receiving incoming S7-S8 s.s.b. signals from the antenna. Generally, incoming S7-S8 s.s.b. signals should be considerably stronger at that setting than the sidebands were during the tests. This all depends upon a subjective judgment if a scope is not available. If a switchable 40dB attenuator is used, it should be used to control r.f. input to the receiver with a constant setting of the r.f. gain control. At center frequency, for example, the full 40dB attenuation is switched into the line and the r.f. gain adjusted for S7-S8 S-meter reading. As the receiver is tuned away from signal frequency, an increasing amount of attenuation is switched out of the line to permit monitoring of voice peaks. At the 8 KHz off-frequency point, all attenuation should be out of the line to permit hearing the peaks. If they can't be heard, that is very good. In simplest terms, there should be

a really big difference between off-frequency sidebands and the on-frequency s.s.b. signal. Incidentally, this same monitoring technique can be applied when checking transmitter output for key-clicks and shaping in the c.w. mode.

(2) Problem Situations. If the above tests indicate that a problem exists below some point in the power range, or across a part of the power range, further checks can provide some clue as to the nature and source of the problem so that remedies can be applied. The station including only a transceiver is at a particular disadvantage, since it cannot be used to monitor itself. In this case, an absorption wavemeter can be homebrewed according to details found in the **ARRL Handbook** or elsewhere, or a CB type unit can be purchased at Radio Shack or other CB outlet. These economical units are adequate. A hamband receiver will permit monitoring harmonic radiation on amateur bands up to 29 MHz or so, while a general coverage receiver is especially useful for checking both for harmonics and unwanted mixing products anywhere in the h.f. spectrum. TV and AM-FM receivers, likewise, are valuable and sensitive indicators of harmonic radiations and spurious signals at around 10.7 MHz and above 50 MHz. Typically, a station will have a monitoring blind spot in the 30-50 MHz range unless a wavemeter is available for that range. However, any unwanted signals in that range usually have harmonics that will be detectable above 50 MHz.

As noted earlier, an irregularity in power reduction in the c.w. mode in the preliminary power reduction tests usually indicates the presence of harmonic or off-frequency radiations which can originate in the transmitter oscillator and mixer stages, or in i.f. and driver amplifiers. Determining the fundamental frequency from which the harmonic is being derived is simple, provided it actually is a harmonic and not a mixing product. Harmonics can be checked with a receiver, wavemeter, or in the v.h.f./u.h.f. range with a TV or AM-FM receiver. Although the typical absorption wavemeter is lacking in sensitivity, it usually is adequate for indications of excessive harmonic radiation if its pickup antenna is positioned close to r.f. output points (or at the antenna).

The frequency band on which the problem occurs provides a clue of the direction to take in checking for harmonics, since harmonics will appear on higher frequencies which are an integer multiple of the fundamental frequency. 160-20 meter signals can be checked simply by tuning to each higher amateur band and comparing signal magnitudes relative to the fundamental. If the above precautions have been taken for isolating the receiver input from the transmitter, most decent receivers with S-meters will provide a fair basis for estimating relative amplitudes. It should be noted, however, that typical receiver gain varies from band to band, while S-meter calibration is constant. So, it rarely can be assumed that an S-8 reading on 80 meters represents the same absolute signal level as an S-8 on 10 meters. If a calibrated h.f. signal generator is available which provides constant r.f. output across the h.f. spectrum, a receiver's S-meter curve can be determined. However, this is not essential to using the receiver for estimating relative magnitudes of fundamental vs harmonics. All harmonics should be a minimum of 40dB below fundamental. Again, a switchable 40dB attenuator is valuable in this context. Hamband and general coverage receivers alike will permit a check of only the second harmonic of a 20 meter signal at 28 MHz, while no checks of harmonics are possible for 15 and 10 meter signals. However, if harmonics of an objectionable level are being generated on 20-10 meters, it is very likely that higher harmonics in the TV and FM v.h.f. ranges will be present.

These can be checked with TV and FM receivers. The correlation between TV channels and frequency bands is provided in the accompanying Table as an aid in locating the fundamental frequency of a problem signal and determining if it is actually a harmonic. Some quick calculations can determine whether a signal monitored on the TV or FM receiver has its fundamental in an amateur band or not simply by dividing the TV/FM channel band limits by the frequency on which the

TABLE. T.V. Channel & Frequency Band (MHz).

Channel	Freq.						
2	54-60	6	82-88	9	186-192	13	210-216
3	60-66	FM	88-108	10	192-198		
4	66-72	7	174-180	11	198-204		
5	76-82	8	180-186	12	204-210		

transmitter is operating. For example, if a strong signal is found on channel 6 (82-88 MHz) while the transmitter is operating on 14 MHz, dividing $82/14 = 5.85$ and $88/14 = 6.28$. If the division process produces non-integer results which cross to the next highest integer (i.e., 5.85 to 6.14), then a harmonic is present whose number is the integer (i.e., 6th harmonic). Degradation of final amplifier output filter performance is indicated as the problem, and here again, resorting to lowered Vcc on the driver-final should clear up the problem. However, if a strong harmonic is found on channel 5 (76-82 MHz) while the unit is operating on 14 MHz, dividing $76/14 = 5.42$ and $82/14 = 5.85$ produces non-integer results without crossing to the next higher integer (5 to 6). This indicates that the problem signal is not harmonically related to the transmitter frequency. If this is the case, the unwanted signal is probably a mixing product or a harmonic of a mixing product. S.s.b. transmitters use at least two oscillators and mixers, and the possible combinations of mixing products are astronomical. When a solid-state unit is operated at reduced drive while the balanced modulator is unbalanced and the final amplifier mismatched to the filter as discussed earlier, just about anything is possible! Hence, if this monitoring test produces results such as those above, it will be necessary to resort to the modifications discussed earlier for lowered Vcc to the driver-final stages.

One method of locating the source of the unwanted signal is to scan around the carrier oscillator and h.f. oscillator frequencies and their 2nd or 3rd harmonic frequencies to determine if they are the source of the problem signal. A general coverage receiver is necessary for this check. For example, if a strong "birdie" is found at around 16.52 MHz and the unit's v.f.o. operates in the 5.5-6 MHz range, the "birdie" is the 3rd harmonic of this internal signal. Since TV channels are 6 MHz wide, the division approach noted above will produce integer results for all channels for a v.f.o. which operates at under 6 MHz. That is why the general coverage receiver is valuable. If the scanning check shows "birdies" at frequencies which are not harmonics of the v.f.o. or heterodyne oscillator, then mixer products are the culprits. Basic circuit modifications are usually out of the question, and changing the approach used to reduce output power should eliminate the problem.

To summarize, the methods used to generate the c.w. carrier in c.w./s.s.b. units, in combination with drive control reduction of output power to drastically lower levels than that for which the unit was designed, together pose potential problems. If harmonics of the fundamental frequency, the frequencies of v.f.o., heterodyne oscillator and mixer stages, and mixing products are encountered, the method used to obtain reduced output must be altered. An unwanted mixing product traced to one of the oscillator or mixer stages and enhanced by the mismatch between final amplifier and output filter can be corrected by operating the mixer stage at full gain and lowering Vcc to the driver-final to provide a proper match to the output filter. Or, the unit can be operated at a higher output level and power in excess of 5 watts dissipated in a resistive attenuator. If distortion and spurious sidebands are encountered in the s.s.b. mode, these two approaches will be necessary. In general, a bit of study and logical circuit analysis is required to determine which change in operating conditions causes the problem at reduced output. The **ARRL Handbook** sections on mixers and balanced modula-

tors provides sufficient information about proper operating conditions of these types of stages to permit trouble shooting. In closing this section, I should note that a great many transmitters and transceivers of all types and vintages have been operated successfully at QRP power levels by means of the strategies discussed here. This discussion about dealing with potential problems is intended to provide some insights in the rare case where a problem occurs.

V. Commercial QRP Equipment

A second option open to the newcomer to QRP is the purchase of commercially produced QRP transmitters and transceivers, both in new and used condition. Since QRP units don't use costly high-power final amplifier circuits and power supplies, a considerable price reduction accompanies the marketing of QRP gear. For example, the last Argonaut 515 retailed for \$429 (p/s \$34 extra) and included all of the features of the economy line high power solid-state transceivers on the market, yet the total investment was about \$300 less than those QRO units. Even better deals can be had by turning to the used market, where a good Argonaut 509 with p/s can be had in the \$200-280 price range. Used 515's, although rare, are slightly higher. Only a few full-feature QRP transceivers have been marketed, primarily by TenTec, Inc, but several c.w.-only types have appeared. A brief survey of these will alert the reader to potential good buys for starting out in QRP operation with QRP equipment.

TenTec, Inc., pioneered the QRP market by introducing a series of QRP modules back in 1969, including v.f.o., transmitter (80-15 meters), and receiver modules. These could be assembled into a complete transceiver by the homebrewer, and TenTec incorporated them into the first solid-state QRP transceiver to appear on the market, the PM-1 "Powermite", a unit featuring bandswitched operation on 80-20 meters (15 meter operation with crystal control) at an output of about one watt. The "Powermite" series developed rapidly into the PM-2 series, with one watt operation on 80-40-20 meters, culminating in the PM-3 series with 5 watts input on 40-20 meters. These units provided dependable service for many QRP operators, but they were part of TenTec's continuing development of solid-state techniques aimed ultimately at the production of the Argonaut 505, the first full-feature c.w./s.s.b. QRP transceiver to appear. Quite a bit of ingenious engineering was evident in this first of the famous Argonaut series which appeared in late 1971. Performance was first rate at 5 watts input (2-3 output). Problems developed in the bandswitches used in early models which exhibit intermittent contact, but a different bandswitch was substituted early on and that problem solved. Thousands of 505's were operated from all parts of the globe because of the unit's portability and operability with d.c. lantern batteries as the power supply. TenTec upgraded the unit to the 509 in 1977 with the addition of several features, including broadbanding in the transmitter section, and finally, upgraded to the 515 in 1980. Production of the series ceased in spring, 1983.

When considering the purchase of a used 505, determine whether the unit suffers from either of two problems. First, early models can exhibit the bandswitch intermittency mentioned above, resulting in random frequency jumps as expansion, contraction and jarring causes switch contacts to relocate with respect to each other. Second most 505's have a tremendous number of operating hours, and in some cases, the driver transistors Q2-Q3 have "gone soft". Q2-Q3 are located in the r.f. front-end assembly and are a pain in the neck to replace. R.f. output from a unit whose drivers have not deteriorated should be in excess of 2.5 watts on all bands (B + supply of 13.6 volts). Driver deterioration will typically result in a noticeable drop in r.f. output on 15-10 meters to one watt or less. TenTec factory service is excellent, but will add to the price of such a unit. If the seller can be talked down about \$25, either of these problems can be solved at

the factory, with the total expenditure for the serviced unit in the \$150 price range. As usual, if the power supply is not included in the price, one must either be purchased (about \$35) or homebrewed. However, the unit can be operated from a pair of 6v lantern batteries for considerable periods of time.

509's and 515's are still relatively new and the second problem noted above should not crop up for a while, if at all. The 509 is a reliable purchase in the \$220 price range, while 515's at \$300 are good buys. The i.f. filter in all three models has a bandwidth of 2.4 KHz, and c.w. operation in crowded situations is tedious. Contemplate the addition of the TenTec optional c.w. filter (about \$35) or an MFJ CWF-2 or CWF-4 if c.w. operation is intended (see "Improving C.W. Selectivity in the Argonaut," **CQ**, January, 1977). Alternately, an active IC c.w. filter can be homebrewed with a response curve tailored to the operator's preference and used with the Argonaut.

Heath followed TenTec into the QRP market with the introduction of the HW-7 QRP transceiver. The unit was basically an embarrassment because of poor design and performance and spawned a whole series of modifications articles, most of which required gutting the receiver section and adding a new circuit. My advice is to avoid purchase of an un-modified HW-7 — at any price! The HW-8, marketed in 1977, is quite a different story! It represents design and performance worthy of the Heath tradition. The unit utilizes a heterodyne oscillator system and provides highly reliable c.w. transceiver operation on 80-15 meters with about 1.5 watts r.f. output ($B + = 13.6$ volts). The receiver section includes a tuned r.f. amplifier ahead of the balanced mixer, followed by a two-stage active audio filter switched from the front panel. The HW-8 is a superb piece of gear and can be found in the \$100 price range on the used market. I tested the unit and thought so highly of it that I went ahead to modify it into a really super rig (see **CQ**, "The Heath HW-8 QRP Transceiver" test report, May, 1977; "Super Modified HW-8 Contest Machine," Part 1, August, 1977, includes 15 meter receiver improvement, additional two stages of c.w. filtering, conversion of relative output meter to Breune in-line SWR wattmeter, pilot light; Part 2, October, 1977, receiver incremental tuning (RIT) circuit and loudspeaker). Reprints of this series plus additional miscellaneous mods, including conversion to 30 meters, are available from me for \$7.00 — proceeds support the Milliwatt DXCC-QRPp Program). Heath announced the replacement of the HW-8 by the HW-9 in late winter, 1983, but by the end of the year, the unit has not appeared on the shelves, presumably because it required additional time for debugging.

MFJ Enterprises replaced TenTec in the QRP module business with the marketing of the MFJ-40T 2-watt crystal controlled transmitter for 40 meters, and the companion MFJ-40V v.f.o. The units can be easily modified for 80 or 30 meters if desired (see "Putting the MFJ Modules on 80 Meters," **CQ**, October, 1975), or assembled into a super-miniature v.f.o. transmitter ("The 'Giant Flea' QRPp Transmitter," **CQ**, July, 1975; **The Milliwatt**, June, 1975). It is not clear whether the modules will still be available by the time this appears in print, but a query to MFJ Enterprises, Box 494, Mississippi State, MS 39762, should produce information. Another single band unit was produced by Kantronics as the "Rockhound" for 40 meter operation, crystal controlled, at about 1.5-watts output, but was discontinued several years ago.

Atlas Radio introduced a new concept in transceiver module design with the 110-S QRP (optional QRO) transceiver back in 1979. The major portion of the transceiver circuit was housed in the receiver unit, while transmitter circuitry was put in a separate enclosure which bracket-mounted to the receiver. Excellent c.w./s.s.b. performance at up to 10 watts r.f. output was possible with the combined units. The units were produced only for a short while, and then withdrawn pending modification of the design and repackaging in a smaller enclosure. Then Atlas went bankrupt. Most unfortunate. The receiver front-end used 3-pole bandpass

filters into a hot-carrier diode ring mixer for outstanding immunity to overload. The vernier tuning mechanism was a joy to operate with, and the unit included RIT. A few appear on the market occasionally and are worth snapping up on the spot. I wish I'd have kept the one I tested for a **CQ** test report.

Yaesu produced a top-quality, small-sized QRP transceiver in the FT-7 for several years, but never marketed it with any emphasis in the U.S., although these units are common in the U.K. The i.f. filter in the FT-7 is superior to that in the Argonaut series, and many veteran QRP operators recommend the unit highly for c.w. operation. The FT-7 is capable of up to about 10 watts r.f. output on all bands, c.w./s.s.b. Very few appear on the used market, and one must be ready with cash in hand to snap them up. Take a quick look and then buy it. Finally, Tedco produced a singleband 80 meter transceiver capable of 500mw output across 100 KHz of that band, depending upon the model number (Model 1 for Novice band, Model 2 for general band). The unit may appear on the used market, and except for its size and low output, it is an ingeniously designed and painstakingly hand-crafted transceiver worth having. Details can be found in the test report in **CQ**, August, 1980.

In addition to QRP-only units, several companies have appealed to the QRP market by including a QRP option in their transceivers. Heath was the first to do this in the SB-104, a state-of-the-art digital readout QRO unit with a switch for dropping instantly to the one watt level. The HW-104 is the economy model, with the same circuitry but not the digital readout. Most recently, TenTec replaced the Argonaut with the Argosy, the first commercial unit designed for both QRP and QRO operation. Internal switching selects the proper biasing for QRP or QRO operation, and at \$549 (minus p/s) the unit is proving popular. Ads in current magazines can be checked for details. Similarly, Kenwood introduced the TS-130V, the QRP version of the TS-130S, with excellent operational features including shiftable i.f. passband and the like. However, the price-tag reflects the features.

Chapter 5

Homebrewing the First Rig

It should be clear from the preceding chapter that the newcomer has a wealth of commercial equipment to choose from in assembling his first station. However, if you want my opinion on the subject, it's this: the only way to taste the joys of QRP to their fullest is to build the first transmitting station, or at least part of it! A QRP contact with any kind of equipment is a thrill in itself. But it is much more satisfying when you do it with equipment that you built from scratch. When that first operator comes back to you, that's a real "high" — ham radio in its purest form, just the way our predecessors in the early days enjoyed it. Ask any QRP veteran about the rig he uses most regularly. If he's done any building, he'll probably say: "Well, I've got a nice Argonaut, but I'll usually hook up the little homebrew rig and make a couple of QSO's unless it's a contest." The commercial gear has all the frills — knobs and switches and smooth tuning mechanism — and perhaps performs a lot better, but it can't compare with the homebrew rig in terms of real satisfaction. But there is a more important reason for homebrewing the first rig. It is the best way of learning about circuit theory and operation, and getting "hands on" experience in assembly and adjustment.

Naturally, most newcomers are reluctant to undertake a project before learning everything about homebrewing. Assembling a test instrument kit such as the Heath IM-5284 FETVM (see Section II.1 below) is excellent preparation for build-

ing a rig from scratch, since the highly detailed Heath assembly instruction manuals include basic information about techniques for the kind of newcomer who has never heated up a soldering iron before. And an essential piece of test gear is produced which is necessary for future building projects. I highly recommend such a kit as a first project prior to taking on a "from scratch" project. Most of what is to be learned can only be learned by going through the complete process, and a kit provides valuable experience. There are many decisions to make in a "from scratch" project, parts to locate, crafting techniques to master, and mistakes are part of the process. The decision to begin a project includes the expectation of such mistakes, but if it also includes a commitment to patience, success is assured. There are many questions that will crop up in the project: which circuit design to build, where to get the parts, what tools will be needed, what kind of test equipment is necessary for testing and adjustment, how to make a printed circuit board (p.c. board), and so on. Hopefully, most of these questions will be answered in this chapter.

I. Circuit Selection

First off, a realistic first project should be fairly simple and not require exotic parts or specialized construction approaches. The most non-critical unit in a QRP station is the d.c. power supply. If the circuit provides a well-regulated d.c. voltage source, that is all that matters. There is nothing critical about wiring or layout, and no parts need be fabricated by the newcomer. This is the logical place to begin. Once a power supply is underway, the next step is selection of a transmitter circuit. This will be a singleband c.w. design, eliminating the possible complexities involved in a multiband design. The selection of the actual design should take into account several factors. Finally, a v.f.o. circuit can be selected to complete the transmitting station. My suggestion is that the newcomer acquire a commercial general coverage receiver, such as those discussed in the previous chapter, because it can double as a very valuable piece of test equipment when building progresses to r.f. circuits such as transmitters and v.f.o.'s.

(1) Power Supply. With respect to a power supply circuit, the primary consideration is the voltage and current it will supply at a specified level of voltage regulation. Regulation is usually expressed as a percentage, and excellent regulation is desirable — on the order of less than 1% output variation going from no-load to full load. First, regulation is important for frequency stability in v.f.o.'s and transmitters. Next, poor regulation can produce chirp in the keying waveform of a transmitter. Since most power supply construction articles don't mention this operating specification, there are a few clues that are useful. Every solid state supply utilizes a large electrolytic filter capacitor at the output of the rectifier. (The reader can glance at the d.c. supply circuit shown in Fig.19). The value of the capacitor is a prime determinant of the regulation figure that will be possible for the stated current output of the supply. A 3 amps supply which uses only 4000mF is not going to exhibit good regulation. Usually a d.c. supply employs a single integrated circuit regulator. In some cases, greater current handling capability is obtained by adding one or two pass transistors to the circuit — their function is to pass the major current flow, and they are controlled by the regulator device. As will be noted in the discussion of the d.c. supply shown later, modern regulator I.C.'s are available to handle as much current as any QRP installation is likely to require. Stick to a circuit which employs such a device.

The voltage-current rating is the next consideration. Most QRP transmitter and v.f.o. circuits are designed to operate at 12-13.6 volts d.c. and use transistors which operate efficiently at that level. Given that voltage level, the current required can be estimated through simple Ohms Law multiplication, where $I = P/V$, where P = total watts dissipated by the rig, and $V = 12\text{--}13.6$ volts.

Most two-watt transmitter projects will be handled by a 1 amp supply. Five-watt designs, such as that shown later in this chapter, require a bit of extra margin, making a 1.5-3 amps supply the logical choice. Actually, count on adding other projects which will be powered by the central supply, and start off by building one that will handle the load later. When ordering parts for a d.c. supply, select a transformer that exceeds the current requirement. Transformers don't always live up to manufacturer's specifications — this is true of Radio Shack units, which should be avoided. Rather than purchasing a brandnew filter capacitor, locate surplus units in want-ads — the computer world has dumped millions of top quality filter capacitors onto the market at real bargain prices.

(2) Transmitter Circuit. Selection of a transmitter circuit should be guided not only by the details of the circuit, but also by the circumstances in which it will be used. Many of the factors noted in the discussion of planning in Chapter 3 apply here. The necessary r.f. output often can be determined by those factors. For example, the type of antenna to be used is a key factor. If a minimal antenna is all that space permits, as is often the case with apartment dwellers or individuals living on small city lots, it is only realistic to recognise that a "Sardine Sender" which develops 700mw output is going to produce a lot of frustration when hooked to a shortened 80 meter dipole at 25 ft. or a trap vertical over four short radials. Given a minimal antenna, a circuit which can develop a hefty output (up to five watts, of course) is the best choice. On the other hand, operation on 15 meters with a 3 element yagi at 50 ft. will not require emphasis on a full five watts output. A 750mw transmitter will do well feeding such an antenna. Similarly, objectives are important. Rag-chewing on 40 meters during the day is feasible with one watt to a dipole up 25 ft. But shooting for WAS-QRP with this one watt setup is not advisable, especially from a location near either coast. In short, many cute circuits have appeared in the magazines amidst authors' claims about how easy it has been to work everywhere with a wet noodle. Forget it. Assess your own situation, and then decide if the r.f. output level of the design is likely to get out with your antenna in the context of your objectives. While the essence of QRP operation is to sacrifice the power advantage, there is no point in going beyond the point of diminishing returns. The difference between 1 watt and 5 watts is about an S-unit (5db), and a couple more dB down to 500mw. Starting out with a marginal antenna which subtracts 3-6dB from what is possible with a very good antenna, and then sacrificing 5dB from the 5-watt QRP maximum through selection of the wrong transmitter circuit, you end up with 8-11dB power disadvantage in addition to that sacrificed by dropping from 100 watts to 5 watts. The point should be obvious: given a marginal or decidedly inferior antenna system, select a circuit that can develop as close to 5 watts r.f. output as possible.

The chief clue to the r.f. output that a circuit can develop is the final amplifier transistor. The **ARRL Handbook** lists the specs for quite a few popular r.f. transistors, and some suppliers (like Circuit Specialists — see below) list the power output capability and gain figure for their devices. Check the final amplifier transistor in a circuit against the output ratings listed there, and then subtract about 20% for a realistic estimate of what the circuit will do. Some general guidelines can also be applied. Avoid circuits using "antique" transistors. These older devices bear the "2N----" prefix and suffix numbers under 5000, and lack the built-in self-protection features of current types. They are prone to self-oscillation and self-destructing thermal runaway as well as various forms of instability. Older devices bearing the "2N-" prefixes are very reliable if they are designed specifically for large-signal r.f. applications and are of the "ballasted emitter" type. These generally have suffix numbers larger than 5000, as in the 2N5589 used in the transmitter circuit discussed later in this chapter. These units usually are conservatively rated by the manufacturer and will develop output in excess of the rating, provided heat-sinking is adequate. For example, the 2N5589 can be pushed to 10 watts

output without ill-effects. Older devices such as the oft-seen 2N2222 are lucky to put out 800 milliwatts. The 2N4429 is a hot device but prone to instability. Overall, stay away from circuits using these older devices (less-than 5000 suffix number). Current state-of-art types are labeled with non-numerical prefixes such as in the small-signal MPS6514. Devices designed for CB use, such as the Motorola "MRF-" series are very hardy and stable and rarely self-destruct except when exposed to extreme conditions. Avoid the temptation to substitute a modern device into a circuit designed for an older type. This approach can be tried on the "let's see if it works" approach, but don't expect it to work right off. The operating characteristics will probably be different enough to cause problems. Before such substitution is attempted, compare the specifications of both devices, and if the gain-bandwidth figure (fT) and rated supply voltage for which it was designed (Vcc) are different, the circuit configuration probably must be redesigned before the substitution will work. Learn some solid-state amplifier circuit theory first, and then do the design change. The standard work — sometimes referred to as "the QRP homebrewer's bible" — is Hayward and DeMaw's **Solid State Design for the Radio Amateur**. It is excellent and I recommend it highly as the book to purchase after the **ARRL Handbook** and **ARRL Antennabook**, assuming, of course, that you've purchased this book first! One final note and this is perhaps the most important point: **USE ONLY HIGH QUALITY, FACTORY-MARKED R.F. TRANSISTORS IN A V.F.O./TRANSMITTER CIRCUIT.** The replacement lines from RCA ("SK" series), GE, Sylvania, and others **SIMPLY WILL NOT PERFORM TO SPECS.** Further, never, never use a Radio Shack substitute. I don't know how many times someone has written to me or called me with a problem involving a newly built transmitter or v.f.o. that won't work, where the problem has been one of these cheapie substitute types. Invariably, after I convince them to get a "real" transistor, the circuit performs as claimed in the article.

Although we're focusing on transmitter circuit selection now, a very important point should be noted: **V.F.O. FREQUENCY CONTROL IS ABSOLUTELY ESSENTIAL TO SUCCESSFUL QRP OPERATION.** Unfortunately, most of the simple attractive transmitter circuits found in amateur radio magazines are crystal-controlled designs. This creates a severe limitation in QRP operation. Calling "CQ" with QRP has been found to be quite unproductive. Hence, the QRP operator must be able to move to the frequencies of stations calling "CQ" in order to make contacts. Unless a box of crystals is at hand, the crystal-controlled QRP operator can end up sitting on an empty frequency all afternoon, day after day. Some simple circuits address this problem by incorporating a variable crystal oscillator (v.x.o.) feature in the design. In this approach, the frequency of a single crystal is "rubbered" ± 5 KHz to provide some frequency flexibility. I've found v.x.o. circuits more troublesome and too inflexible to make them worthwhile. I've never doubted that the author achieved the smooth 10 KHz frequency variation he claims — and so would I, if I had his specific crystal! However, I should note that the "OXO" and "STX" circuits featured in **SPRAT** perform reasonably well using the v.x.o. approach and I can recommend them as a first project, bearing in mind the restriction on frequency flexibility that will result. The G-QRP-C has offered both in kit form. Evenso, the best approach is to select a circuit which is capable of being driven by a v.f.o. in the future, but operable with crystal-control at the moment. About the only guarantee that this is possible is when the author includes a v.f.o. circuit which drives the transmitter, or refers to a published circuit which he has used to drive it. Otherwise, mating the transmitter with some v.f.o. circuit found in another article has a 50-50 chance of not working.

(3) V.F.O. Selection. V.f.o. circuits are especially critical in regard to frequency stability and r.f. output. It is difficult to judge a given circuit without some knowledge of circuit theory. But some points can be considered in examining a prospective circuit. "Pulling" of the v.f.o. frequency by the transition from key-up

to key-down full load conditions can be spotted as a possible problem by examining several aspects of the circuit. The power developed by the oscillator stage is delivered to the next and subsequent stages through coupling capacitors (see C6, Fig. 14 below). Generally, these should not exceed about 100pF in order to prevent undesirable loading effects (see comments in Section V.1). Further, r.f. isolation is important in preventing frequency pulling. Unless the part of the circuit delivering the B+ voltage to the oscillator stage includes a bypassed r.f. choke between the second stage (buffer-amplifier) and the oscillator (see RFC1, Fig. 14), there is a likelihood that pulling will occur because of r.f. energy traveling back to the oscillator stage from later higher power amplifier stages. Likewise, poor regulation of the B+ voltage to the oscillator will result in frequency pulling. A zener diode should appear in the circuit at a point where the B+ lead goes to the oscillator transistor or FET (see D2, Fig. 14).

Next, one buffer-amplifier stage between the oscillator stage and the transmitter circuit is rarely adequate to buffer the oscillator from shifts in operating conditions caused by a change in the r.f. load presented by the transmitter. Hence, avoid a v.f.o. circuit which does not incorporate two buffer-amplifier stages between oscillator stage and output port. Once a circuit is selected, exercise care in selecting the parts to be used. While silver-mica capacitors are frequently used in the oscillator frequency-determining loop, polystyrene, tantalum or N.P.O. disc ceramic types provide better thermal stability. Further, avoiding cheapie low-quality transistors is even more critically important in a v.f.o. than in a transmitter. If the prospective circuit utilizes Radio Shack or the substitute lines mentioned above, don't attempt to duplicate it — putting high quality transistors into will change operating ranges enough to lead to problems. Finally, exercise considerable care in construction — comments about this appear later in the description of two v.f.o. circuits.

II. Test Equipment for Homebrewing

Most published designs will work right off the bat, provided that no wiring errors have been committed, the p.c. board duplicates the author's design, and high quality components are used. The tips given above about selection should guide the newcomer to a good design, but he should bear in mind that the above advice is no substitute for learning the basic theory and how to analyze a circuit. When problems do occur after assembly (including wiring mistakes etc.), some basic test gear is needed in order to debug the unit. Even when something works, the urge usually arises to determine how well it is working, and to peak the unit to highest efficiency. Fortunately, and newcomers frequently don't realise this, one does not need an expensive Hewlett-Packard test lab to debug a malfunctioning circuit. All that is needed is some simple test equipment and an understanding of how to use it. That means understanding enough basic theory so as to know what measurements to make and how to interpret those measurements. While a discussion of theory is beyond the scope of this book, it will be helpful to survey the basic test equipment that will enable the homebrewer to troubleshoot and debug projects. The following items are listed in the order in which they could be acquired.

(1) VTVM/FETVM/DVM. The first item to acquire is a d.c. voltmeter — either a vacuum tube or transistor type. The input impedance of inexpensive VOM's (volt-ohm meter) which incorporate neither tubes nor transistors/FET's is too low for practical purposes, and these units should be avoided. The VTVM/FETVM is usually an analog device in which readout of measured volts, amperes/milliamps, and ohms is via a meter scale and dial-pointer. A DVM (digital voltmeter) is essentially the same, except that readout is via LED numerical display. While the digital readout is more impressive, the analog meter permits more effective monitoring

of voltages or currents which swing while adjustments are made. Such swings appear as a blur of unreadable digits on a DVM. This basic instrument permits measurement of voltages at various points in a circuit, current flow through a part of a circuit, and resistances across part of a circuit. A large variety of voltmeters are available on the market, including Heath's IM-5284 FETVM, available in kit form for \$47.95 from Heath, or IM-5218 VTVM in kit form for \$77.95, from Heath Company, Benton Harbor, MI 49022 (Order #5280). Also available are numerous DVM's for under \$90. My preference leans toward a used Hewlett-Packard or Tektronix VTVM. Again, the "yellow sheets" and ham-ads in the magazines are the sources to check. I recently acquired a mint HP-412A for \$35, and my ancient HP-410B is still doing an accurate job — cost \$45 about 10 years ago. Professional caliber units (that's HP and TEK also) range up to \$400 new (RCA, Triplett, Sencore etc) and are excellent investments, if funds are available.

(2) R.F. Probe. Measurement of r.f. voltages is essential in homebrewing. All that is required is an "r.f. probe" to use with the VTVM/FETVM/DVM. R.f. probes provide either an r.m.s. (root mean square) or a peak readout. Either type of reading is convertible through formulae found in Chapter 8. The r.f. probe permits measurement of the r.f. voltages developed at various points in an r.f. circuit. In the circuits shown later, these voltages are included as a guide to proper operation of the circuit. If a duplicate unit doesn't work properly, a measurement of the r.f. voltages will usually pinpoint the part of the circuit which is malfunctioning. The r.f. probe can be used to measure output power across a 50-Ohms dummy load when adjusting a completed transmitter circuit. Heath markets the only r.f. probe available on the market, and it can be used with almost all VTVM/FETVM/DVM units (Order #PK-3A, \$9.95, from Heath Company). However, construction of a probe is so utterly simple there is little reason to purchase a kit — see Chapter 8, Section IV. Many professional voltmeters include an r.f. probe, so choose one that does include the r.f. probe.

(3) R.F. Powermeter/In-line Wattmeter. A wattmeter permits measurement of r.f. power delivered to a load, measured in watts. Two types are available. First, a wattmeter/powermeter includes a 50-Ohms dummy load in its circuit, with a meter directly calibrated in watts delivered to the load. An in-line wattmeter is designed for insertion into the coax cable between transmitter and antenna and measures SWR (standing wave ratio) as well as power from the transmitter. When connected to a 50-Ohms dummy load instead of the antenna feedline, the in-line wattmeter permits measurement of transmitter r.f. output during adjustment. It is the more versatile instrument. A unit can be homebrewed or one of several commercial units purchased. The only criteria to follow is: the unit should be sensitive enough to permit full-scale meter deflection in the 1-5 watt range. Two units for QRP use are: (1) the MFJ-820 Power Sentry with MFJ-832 QRP Sensor (included in unit price), \$69.96, from MFJ Enterprises, Box 494, Mississippi State, MS 39762; and (2) the Heath HM-9, \$49.95, from Heath Company. Construction of a wattmeter and in-line wattmeter is discussed in Chapter 8, Sections III and V.

(4) 50-Ohms Dummy Load. A dummy load is connected to the output of the transmitter during testing and adjustment and before hooking the unit to an antenna. The simplest version consists of a 2-watt 51-Ohms carbon resistor (standard type) soldered into a phono plug or coax plug, or across the output terminals of the transmitter p.c. board. Similarly, a pair of 2-watt 100-Ohms carbon resistors will suffice for all QRP testing. When performing r.f. output measurements, the actual value of the resistor is used along with the measured r.f. voltage to determine power. See Chapter 8, Section III for details.

(5) R.F. Attenuator. This general purpose device is used whenever an accurate drop in voltage or power is desired. None are available on the commercial market for less than \$100 or so. The construction of such a device is discussed in the previous chapter.

(6) Field-Strength/Wavemeter. This instrument measures the intensity of an r.f. energy field such as is generated by a transmitter. When calibrated vs frequency, it is valuable in determining where in the spectrum a v.f.o. or transmitter is generating r.f. energy. It is used to detect the presence of harmonics (i.e., signals that are a multiple in frequency of the desired frequency) or spurious products. Units are available in most CB outlets for under \$15.

(7) Frequency Counter. Permits very accurate measurement of operating frequency of a v.f.o. or transmitter. Many units are on the market for under \$90.

(8) R.F. Signal Generator. An r.f. signal generator is an oscillator which generates an r.f. signal across a wide range of frequencies. It is useful for a variety of purposes. For example, a tuned circuit can be peaked by being fed a signal of the correct frequency and adjusting the circuit for maximum r.f. voltage. The Heath IG-5280 is a basic unit providing 100mV output from 310 KHz to 110-MHz in kit form for \$47.95, and is adequate as a first purchase. However, it lacks features found on more expensive, higher quality units, such as constant r.f. voltage output across the entire range, built-in calibrated attenuator (permitting the r.f. output to be adjusted to extremely low levels), and high output (5-10 volts, peak-peak). Again, the "yellow sheets" often shows Hewlett-Packard and Tektronix used units for under \$150, and they include the above features. My TEK-190B cost \$90 and has been worth every penny of it for the past 8 years.

(9) Antenna Noise Bridge. Also termed an "RX" or "Z" bridge. This instrument is used in adjusting antennas and is essential for tuning multiband trap verticals, yagis, quads and other types of low-impedance antennas (100-Ohms and under). Simple wire antennas such as dipoles and inverted Vee's should be cut to formula length and operated at that length. The MFJ Enterprises MFJ-202 Noise Bridge at \$54.95 is an excellent instrument employing battleship construction" and I recommend it highly. When pruning and tuning an antenna, DO NOT AIM FOR LOWEST SWR, as is almost universally suggested. Instead, use the noise bridge and TRIM/ADJUST FOR MINIMUM REACTANCE AT THE DESIRED RESONANT FREQUENCY. See Chapter 8, Section VI for comments.

(10) Antenna Transmatch. A transmatch is inserted between the output of a transmitter and the coax cable which feeds the antenna. All feedlines exhibit some reactance at the transmitter end, and this causes mismatch between transmitter and feedline. The transmatch cancels out this reactance, and creates a perfect match ($SWR = 1:1$) between the two. This is often essential for the proper and efficient operation of a solid-state QRP transmitter, since it is not capable of feeding r.f. output to anything but a non-reactive load in the vicinity of 50-Ohms. A transmatch is an important accessory and should be purchased early on. MFJ Enterprises has a wide selection of units. My recommendation is the battleship construction MFJ-901 at \$49.95 — it will match anything!

(11) Oscilloscope. An oscilloscope is the most versatile and valuable piece of test equipment that a homebrewer can possess. A scope permits observation of the actual waveform of an r.f. signal which is displayed on the cathode-ray tube screen (like a T.V. screen). The amplitude of the r.f. waveform can be directly measured, its frequency estimated, and it can be examined for signal impurities, harmonics, and discontinuities that are direct clues to a malfunction. Adjustment procedures are rendered quick and easy, since the effect of each adjustment can be observed directly on the scope screen. An oscilloscope is a very complex instrument, but the newcomer can quickly learn how to make basic measurements with it. The large list of specifications used to define a particular oscilloscope's capabilities will totally baffle the newcomer. A few guidelines will help. First, bandwidth and risetime indicate the scope's frequency range. A bandwidth of d.c. to 30-MHz makes observation of harmonics possible. A "risetime" of about 10 nanoseconds indicates this bandwidth. Generally, economy scopes featuring a bandwidth of 5-or 10 MHz will not be very useful in this respect. Second, a **time**

base or sweep rate of 50-to 100-nanoseconds permits display of a single cycle of an r.f. signal approaching the upper limit of the 30 MHz bandwidth. Slower sweep rates cram many r.f. cycles onto the screen, making observation of waveform irregularities quite difficult. Top quality scopes include a “sweep magnifier” given as 5X or 10X which permits “spreading” the waveform out across the screen so that a closer look is possible. Sensitivity is a measure of the amplitude of input signal required to produce a certain size waveform on the screen. “2mV (millivolts) / cm (centimeter)” indicates that a 2mV r.f. signal will produce a sine curve 1cm high on the screen. This is an excellent sensitivity figure which will permit observing waveforms of very low-level signals, such as occur in pre-amplifier stages. Automatic internal triggering with “high frequency sync” stabilizes high frequency displays. A built-in amplitude calibrator is essential. While dual trace scopes (able to simultaneously picture two input signals) are attractive, the newcomer simply doesn’t need the extra trace. These few essential features can guide the newcomer to the right kind of scope. Bandwidth is the primary consideration. With respect to availability, Tektronix has recently introduced a fantastic scope for the hobbyist — the TEK label guarantees absolute top quality. Hameg, a newcomer to the American market, has also introduced an attractive line for under \$400. Their ads can be found in the ham magazines. Beyond these two, the other possibility (you guessed it by now!) is to pick up a used TEK or HP scope via the “yellow sheets”. My TEK 545B, a superb dual-trace, 30MHz unit, set me back \$150! It is huge and heavy, and difficult to carry up two flights of stairs, but I’ll break my back to save \$300-??? and end up with a Cadillac in the bargain! Once a prospective unit is located, query the advertiser about the specs noted above, the last date of calibration, and request a xerox of the spec sheet. If it has been calibrated within the last year or two, you’re in luck. If longer than five years, it may need calibration, a rather tedious job not for the newcomer. Never purchase a used unit unless a manual is included. It is the key to the operation of the instrument, and the section outlining calibration will provide clues as to what is supposed to happen to the display as various front panel knobs are placed at various settings. Ultimately, every homebrewer should own a good scope. Finally, an **r.f. sweep generator** can be added to the lab. By that time, you’ll know what that unit will do.

III. Parts Sources

Most newcomers experience difficulties locating parts for a project. While the local Radio Shack is a source for “easy” items such as resistors, switches, capacitors and the like, it is difficult to build much of anything out of such an outlet. Sources for several categories of parts are listed below. The five categories of parts are: (1) resistors, capacitors (silver mica, disc ceramic, N.P.O., polystyrene), diodes (zener, small signal r.f., switching, varactor tuning diodes), r.f. chokes, integrated circuits, transistors, FET’s, voltage regulators; (2) trimmer capacitors (Elmenco, Arco), variable tuning capacitors, toroid cores, rectifiers, air-wound inductors; (3) power supply items — transformers, bridge rectifiers, large filter capacitors, fuses etc; (4) hardware — cabinets, 4-40 screws/ bolts, connectors, lugs, heatsinks, vernier drives/dials, drill bits for p.c. boards, p.c. boards, p.c. board kits, etching supplies, switches, pilot lights, LED’s, plugs etc; (5) antenna supplies — coax cable, open-wire feedline, coax connectors, insulators, etc. The following list includes an indication of the type of parts available from a given source. Send for catalogues.

(1) Circuit Specialists, PO Box 3047, Scottsdale, AZ : #1,#2,#4, and best source of r.f. power transistors.

(2) DIGIKEY, PO Box 677, Thief River Falls, MN 56701: #1, no #2, no #3, some #4.

(3) RadioKit, Box 411, Greenville, NH 03048: weak on #1 but good on #2 and #4 — about the only source of superb Jackson Brothers vernier drives for critical frequency tuning applications such as the frequency control of a v.f.o.

(4) KCS Electronics Corp., PO Box 33205, Phoenix, AZ 85067: good on #1 and some #3.

(5) BCD Electro, PO Box 830119, Richardson, TX 75083-0119: leans toward surplus purchases instead of a regular line of parts, but is excellent source for #3 — current catalogue shows a 17000 mF filter capacitor for \$1.00!

(6) Nema Electronics, Inc., Dept Q, 12240 N.E. 14th Ave., Miami, FL 33161, is an excellent source of high-quality coax cable, such as the RG-8/U 97% shield recommended earlier.

(7) Amidon Associates, 12033 Otsego, N. Hollywood, CA 91607: toroid cores, pot cores, slug-tuned shielded cores.

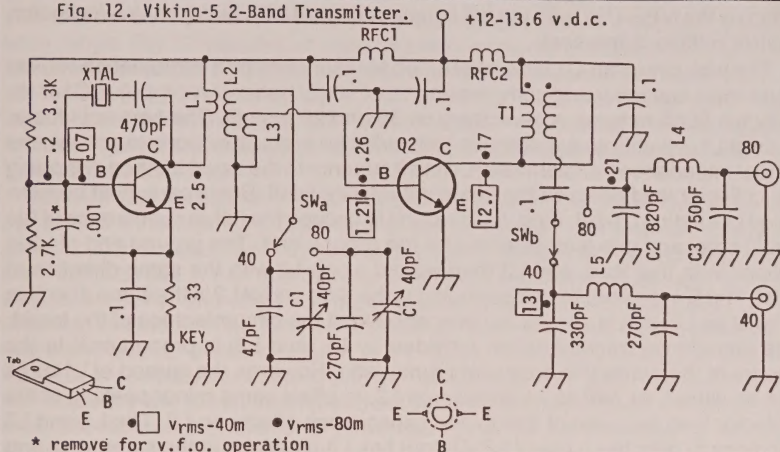
In addition to these sources, a multitude of ads appear in the amateur magazines offering everything that will ever be needed, and frequently at bargain prices. Incidentally, a real hamfest fleamarket is a homebrewer's paradise. In fact, a \$50 bill will result in a shopping bag of parts that will last for years. Typical fleamarket prices are far below retail and the exact same top quality parts are offered. Power supply components usually abound at these affairs, tools can be had cheaply, and hardware is at discount. Test equipment and even general coverage receivers frequently show up. The accepted buyer's strategy is to make several passes by a large item during the afternoon, each time noting some new defect such as a scratch or mumbling something like "sure was a nice piece of gear . . . about a hundred years ago, dunno, dunno . . ." There's a gamble involved — someone else may buy the thing. But if not, sellers don't want to haul gear home — they want to unload it — and closing time brings prices way down.

IV. VIKING-5 Twoband 5-watt Transmitter

Fig. 12 shows the circuit of the Viking-5 twoband 5-watt c.w. transmitter which is an ideal first project for the newcomer. The unit has been constructed by many QRP'rs with only a few hitches in individual cases. If desired, the unit may be constructed for singleband operation, and an alternate p.c. board is provided for this approach. The circuit for the singleband version is the same, except that the bandswitch SWa-b, the tank circuit (C1a-b) and the output PI-network are eliminated for the band that is not used. Fig. 12 includes a table of values for 80 through 20 meters, and the unit may be used on any of these bands. If a twoband version is chosen, however, the two bands selected must be a combination of 80-40, 40-30, or 30-40 because of the method used to operate L1-2-3 on two bands.

(1) Circuit. The circuit is a straight forward design consisting of a Class-A crystal oscillator driving a Class-C amplifier. The base resistors of Q1 establish the proper bias level for Class-A operation. A fundamental crystal for the band in use is inserted in the r.f. feedback path from collector to base, while a .001 ceramic capacitor provides an r.f. feedback path from base to emitter to enhance crystal oscillation as well as stabilize the stage. This .001 feedback capacitor must be removed for v.f.o. operation. The emitter resistor (33-Ohms) provides degeneration for stability and controls the gain of Q1, and with the value shown, the oscillator develops about 400mw r.f. output into a 50-Ohms load. Since the duty cycle of a Class-A stage is almost 100%, the large collector current causes considerable thermal buildup. But the MPS-U31 is easily capable of 5 watts dissipation, and runs mildly warm at full power when the heat-sink tab of the device is soldered to the p.c. board to utilize the p.c. board as a heatsink. Less rugged transistors usually shown in similar oscillator circuits, such as the MPS-6514, 2N706, 2N697 and 2N2222, will rapidly disintegrate from thermal breakdown if placed in the circuit. In designing the oscillator circuit, the objective was to provide a drive signal ade-

Fig. 12. Viking-5 2-Band Transmitter.



RFC1 - 8t., #24, FB-73-801

RFC2 - 7t., #24, FB-73-801

C1 - Elmenco 40pF trimmer

SWa-b - Subminiature DPDT slide switch

XTAL - 3.5- or 7 MHz fundamental crystal

Capacitors in pF - silver mica or tantalum

.01, .1 - disc ceramics

Resistors - 1/4-watt

Q1 - MPS-U31; Q2 - 2N5589

T1 - 16t., 2-wire twisted pairs on T-50-2

toroid core. (1) Twist 2 pieces of #26 to 9 twists/inch; make 2 'pairs'. (2)

Twist the 2 pairs to form a cable with 10 twists/inch. (3) Wind the cable on the T-50-2 core, cut excess cable, and

solder each cable end separately. (4) Solder together beginning end of cable #1 to finishing end of cable #2 and

connect this common lead to Q2 collector. Connect other leads as seen in Fig. 12.

L1-2-3 - See text

Band:	80	40	30	20
C1*	270pF	47pF	60pF*	60pF*
C2	820	330	220	120
C3	750	270	180	120-220
L4	23t #21	15t #21	12t #21	8t #21

(L4 wound on Amidon T-50-2 toroid core)

* 60pF Elmenco 404 trimmer, no fixed capacitor

Bands:	80/40	40/30	30/20
L1	3.5t	3t	3t
L2*	35t	27t	22t
L3	2t	2t	2t

*#24 on Amidon T-50-2

L1-3: hook-up wire, #24

SINGLEBAND VERSION

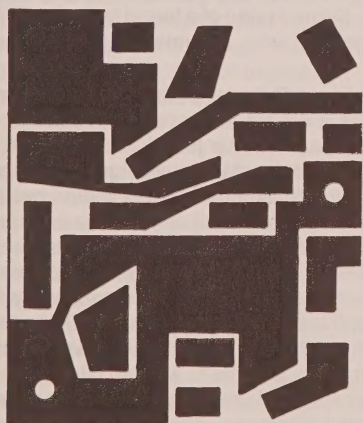
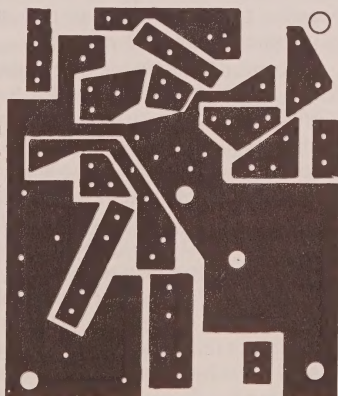


FIG. 16



quate to achieve the full power output capability of the 2N5589 which is rated at 5

watts. Hence, a healthy drive signal in excess of 300mw was required, easily provided by the MPS-U31 with the full supply voltage (12-13.6vdc) as V_{ce} (collector-emitter voltage difference).

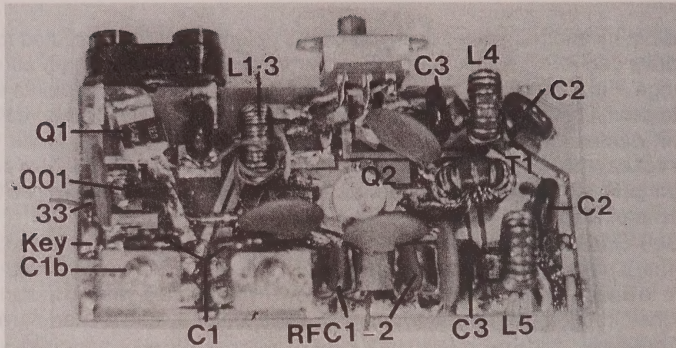
The tank circuit for Q1 is parallel tuned to resonance by a combination of fixed silver-mica capacitor and compression trimmer (Elmenco-Arco type) at C1-C1b. Only the 60pF trimmer is necessary on 30 and 20 meters. The type of inductor used at L1-2-3 utilizes a winding at both collector and output ports to achieve the proper impedance transformation. I find it superior to the usual method of tapping the collector lead down on the tuned inductance itself. Some care must be exercised in winding L1-2-3. First, L1 is wound to occupy the full circumference of the toroid core, and one lead selected for the ground end. The ground end of L3 is spliced with that lead, and L3 then wound along L2 with the same direction of twist. The B + end of L1 begins winding at the SWa end of L2 in the same direction of twist as L2, and is spread out over about half the circumference of the toroid. The impedance transformation provided by L1 (and L3) is proportional to the square of the primary to secondary turns ratio. However, the spread of L1 turns can be varied, as well as its position on L2, to effect some minor peaking of the collector load because of distributed capacitance effects on L2. The L1 and L3 windings fit over the turns of L2. Output link L3 functions in the same way, and matches the typically low input impedance of Q2 to the considerably higher collector impedance of Q1. The oscillator stage is isolated from the amplifier by means of RFC1-RFC2 and associated bypass capacitors. This is necessary in order to prevent self-oscillation from r.f. feedback along the B + leads. For v.f.o. operation, isolation is absolutely necessary to avoid loading effects (chirp, frequency shift) which occur when the unit is keyed. In selecting the r.f. choke, an inductance value of 5-10 times the collector load impedance is usually appropriate (the inductance value must be converted from microhenries to Ohms-reactance to get the proper proportions — see **ARRL Handbook**). An Amidon jumbo bead ferrite core with a permeability ("mu") of 2500 is used to achieve the proper value of inductance with very few turns of a relatively large diameter wire which presents negligible d.c. resistance to collector current flowing through it. A serious drop in V_{ce} (collector-emitter voltage) occurs if a standard r.f. choke wound from minute wire is used in this application. Compression trimmers are included in the Q1 circuit to permit precise peaking of the tank circuits, and allow a bandwidth of about 75 KHz. It would be difficult if not impossible to peak the oscillator circuit using only fixed capacitors. Some tuning of a toroid inductance is possible by spreading apart or compressing the turns, assuming that the toroid inductance is not tight-wound.

The amplifier stage is a straight forward Class-C stage. In this class of operation, a very small amount of d.c. forward bias is developed across the resistance represented by the wire in L3, and across the base-emitter junction of Q2 when a r.f. drive signal is applied from Q1. The positive peaks of the drive signal drive the amplifier into the conducting state for only a small portion of the oscillation cycle. A broadband 1:4 balun transformer, T1, transforms the Q2 collector load impedance of about 9-Ohms to about 36-Ohms. Since the transformer will pass all r.f. energy generated in Q2 across a wide portion of the h.f. spectrum, including v.h.f./u.h.f. harmonics, some type of narrowband low-pass filter is necessary to suppress harmonic signals, as well as match the output impedance of T1 to the load impedance presented by an antenna. A single section PI-network is perfectly adequate in this case, since the output from Q2 is quite clean without filtering and exhibits little harmonic energy. The amplifier stage is isolated at r.f. from the driver stage and B + line by RFC2 and a 0.1mF ceramic bypass capacitor. RFC2 is similar to RFC1 in its construction and function. Output from the transmitter is a pure sine wave with no harmonics or distortion when Q1 is properly adjusted. Since Q1 gain is controlled by the emitter resistor, the 33-Ohms value shown in Fig.12 may

be replaced by another value; or, a 100-Ohms potentiometer substituted to provide a drive control with which to vary power output from the Viking-5 across a wide range. Fig.12 includes r.f. voltage measurements at different points in the circuit to permit testing and debugging should a problem arise. These readings are taken with an r.m.s. r.f. probe and VTVM/DVM. Note that the 40 meter readings (in boxes) are lower than 80 meter readings — this reflects the decreasing transistor gain with increasing frequency. 30 and 20 meter readings will be lower than 40 meter readings.

(2) Self-Oscillation. A note about self-oscillation is in order. Under certain conditions, a transistor in a Class-C amplifier circuit will find a feedback path from collector to base, and begin to oscillate on its own, just as if a crystal or inductance were in the circuit. If p.c. board layout is followed faithfully and all parts are connected properly, and the PI-network output filter fairly well matched to the antenna, this problem will not be encountered. Self-oscillation can be detected in two manners: (a) a sudden jump in r.f. output (accompanied by a massive increase in collector current I_{ce}); and (b) “white noise” or “hash” around the signal frequency and sometimes spread out across a frequency band. The first characteristic reflects the additional power generated in the transistor at full gain across the h.f. spectrum, and the second is a result of the fact that the transistor is not oscillating on a single frequency, but a band of frequencies. If self-oscillation occurs, instantly switch off the B + to stop circuit operation and permit cooling of the final transistor. Then look for the problem. Depressing the key will have no effect in most cases — the self-oscillation continues for a short time until the transistor is “smoked”. Bypass capacitors rarely are defective, but I’ve have been faced with a self-oscillation problem twice due to a faulty disc ceramic, so it does happen. One circuit trick that degrades gain but which usually suppresses amplifier self-oscillation consists of placing a high reactance silver mica from collector to ground (i.e., low pF value, such as 33pF on 40 meters). However, this merely serves to swamp part of the mismatch presented to the final by the output filter. If all r.f. chokes and bypass capacitors are properly installed and the ground foil unbroken around the p.c. board, the problem is very likely related to a mismatched antenna. The antenna feedline may present too high or low an impedance for the filter which is designed for a 50-Ohms load. In such a case, a transmatch (antenna tuner) is necessary, unless the builder has enough experience to experimentally adjust the PI-network filter to accommodate the antenna impedance. Depending upon the sign of the reactance presented by the feedline, network inductance or capacitance must be readjusted for a conjugate match. I don’t recommend this for beginners. The network can be hooked to a 50-Ohms dummy load and the turns of the inductance compressed and spread alternately to note effect upon output. If peak output occurs with some arrangement of windings, the inductance is correct for a match to 50-Ohms. If compressing the turns increases output, but the peak is not reached, an additional turn can be added (or one removed if spreading the turns has this effect). Don’t experiment with the capacitors — they are selected by formula. The actual inductance, however, can be somewhat different from the intended value because of the individual homebrewer’s winding technique. For example, some homebrewers loop the wire loosely around the toroid core; others pull it as tight as possible; and I, for one, bend the wire at a right angle at the outer edges of the core. The three techniques produce a variation in the resulting inductance value.

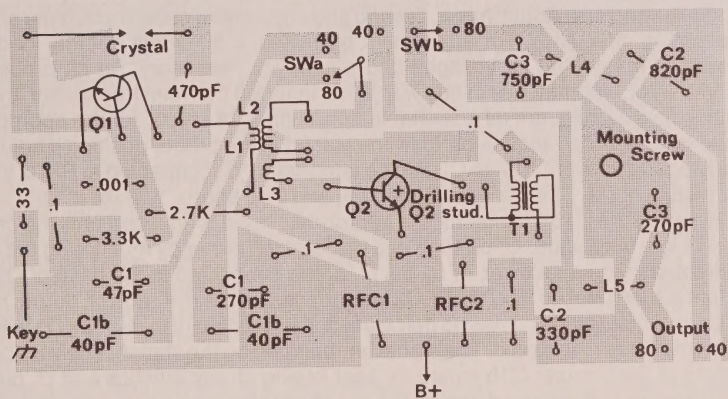
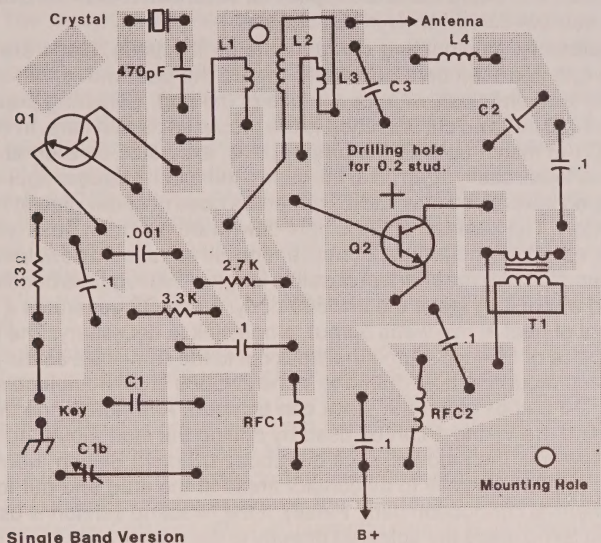
Secondly, interaction of the final amplifier with previous stages can result in self-oscillation. An r.f. feedback path can occur along the B + line. In this case, a quite small amount of r.f. current travels back along the B + line and through L1. L1 inductively couples this sample to the base of the amplifier through L2-3. This creates the same effect as L1 in the v.f.o. circuits shown below. Hence, RFC1-2 and bypass capacitors perform a critical function in as much as they eliminate this



potential path. The only other possible path is created by the base link L3. Beginners sometimes make the mistake of assuming that the number of turns in the link winding controls the amplitude of the drive signal to the base of the final — so, if the rig develops 3 watts output with a 2 turn link, it should do 5 watts with 3 turns. Not so. The number of turns in L3 functions only to obtain the correct impedance ratio to L2; the same is true of L1. Maximum power transfer occurs when the impedance transformation is correct for L1:L2 and L3:L2. Hence, newcomers are sometimes puzzled that output from the final increases with a decrease in the turns in the link winding (or the collector winding). Some designs insert a low value resistor (22-Ohms or similar) between the L3 link and base of the amplifier. This is usually a band-aid remedy when major surgery is needed in redesigning the tank circuit itself for correcting r.f. interaction. Self-oscillation caused in the base circuit of the amplifier usually is due to a mismatch created either by L1 or L3.

(3) P.C. Board. Fig. 13 shows alternate p.c. boards for either a singleband or twoband (parts overlay shown actual size) version. The “isolated pad” approach is used for two reasons: (a) use of a device such as the 2N5589 requires that the connecting foils be on the same side of the board as the device is mounted upon; (b) the isolated pad board is simpler to fabricate than the type with connecting foils on the underside. This approach to p.c. board fabrication is discussed in detail with photos in an earlier article (“Easy P.C. Board Fabrication Using Address Labels,” **CQ**, March, 1978). Briefly, the p.c. board stock (double copper-clad — copper foil on both sides of the board) is cut to template size, and self-adhesive address labels taped to both sides of the board. Since this approach was developed, self-adhesive address labels appear to have deteriorated in quality, so that some begin shredding away during the late stages of the etching process. Select labels with substantial adhesive and as glossy a paper as possible. One homebrewer suggested using a brown plastic tape that can be found in most plumbing and heating shops. This tape is used to wrap natural gas pipes. Next, a tracing or xerox of the template is glued to the side to be etched, and a ruler and sharp-tipped penknife or razor blade is used to cut along the outlines of the pads. Once all lines have been inscribed, the tip of the knife is used to remove all label material (or tape) which covers the copper areas to be etched away. The board is then placed in full strength etching solution until the unwanted copper foil is etched away. Agitate frequently to speed up the process. One homebrewer uses a Mason jar full of etching solution; he simply places the board in the jar, and shakes the jar every 30 seconds. Finally, all label material is scraped away and the remaining adhesive steel-wooled off until the clean, shiny copper pads remain. Assembly can then proceed. Alternate methods of doing the p.c. board include using an

Fig. 13 Viking-5 Transmitter



etch-resist pen to draw the template directly onto the foil, or using a rub-on etch resist instead. P.c. board kits and supplies for several methods are available from the parts sources listed earlier in this chapter.

(4) Assembly. In mounting components on the pads, leads are cut to the proper length and then bent downward toward the pad, with another bend that makes the lead end flush with the surface of the pad. Soldering proceeds. The leads of L1-2-3 must be cut and fitted to the proper pads with care. In bending the leads of Q1 to match up with the proper pads, exercise considerable caution, since these leads easily snap off at the case if too much torque is applied to them. I've snapped several, so now I add a generous dose of epoxy glue at the case for extra support. The heat-tab of Q1 is bent downward and then flush with the pad, and soldered. When mounting Q2, both emitter straps should be soldered directly to the ground foil with the shortest possible length. This requires bending the tabs downward where they leave the 2N5589 body. Since Q2 generates a considerable amount of heat at five watts output, a heatsink is necessary. The heatsink is simply a piece of 1/8-inch aluminum stock cut to the same size as the p.c. board, with the stud mounting hole drilled to fit the 2N5589 stud. If 1/8-inch stock is not available, 2-3 pieces of thinner stock can be used. Alternately, the metal enclosure housing the Viking-5 can be used by drilling the stud mounting hole in the bottom. However, the stud will stick out about 1/8-inch! Silicon thermal grease should be applied liberally to all contact areas at the stud and nut to insure an efficient thermal conduction path. Finally, if the twoband version is used, crystal socket and SW-b leads are soldered directly to the proper pads.

(5) Testing and Adjustment. Testing and adjustment of the transmitter should present no difficulties. For adjustment purposes, a 50-Ohms dummy load and means of measuring r.f. voltages and output are necessary. An r.f. probe and VTVM/DVM, wattmeter, or in-line wattmeter inserted between transmitter and 50-Ohms dummy load, are all acceptable approaches. A crystal for the appropriate band is plugged in (and the bandswitch placed in the proper position if adjusting the twoband version). B + to Q2 can be temporarily disconnected at RFC2 to permit testing of Q1. The B + is switched on, and if no shorts "smoke it", the unit is keyed while the C1b trimmer for the appropriate band is adjusted until the crystal breaks into oscillation. Oscillation can be detected either by monitoring the crystal frequency on a receiver, or by the r.f. probe connected to the base of Q2. Q1 output is then peaked by C1b. RFC2 is connected to the B +, and r.f. output monitored on whatever instrument is being used. It is necessary to re-peak Q1 with the final amplifier in the circuit. The signal is monitored on the station receiver and the setting of the trimmer C1b varied for best keying characteristics and r.f. output. The receiver is then tuned across the spectrum above and below the signal frequency to verify that no parasitics are being generated. These sound like "hash" noise on the receiver. If power output is 4 watts or better and no hash is detected, adjustment is completed and the transmitter can be put on the air. See the "Monitoring Signal Purity" section of the previous chapter for further test procedures. In the units tested, no problems at all have been encountered, and adjustment was a breeze.

V. Singleband V.F.O. for the VIKING-5

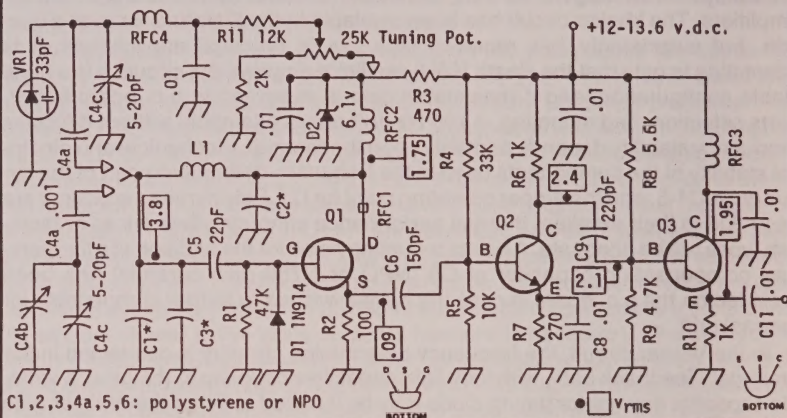
One limitation of the Viking-5 is that it is a crystal-controlled design. The versatility and effectiveness of the rig can be greatly enhanced by the addition of v.f.o. frequency control. In this section, details for a v.f.o. circuit capable of driving the Viking-5 to full output are presented. When this v.f.o. is combined with the singleband version of the Viking-5 and mounted in a 1.25 x 2.25 x 4.25 inch box, a very compact 5-watt v.f.o. controlled transmitter results.

(1) Vackar V.F.O. Circuit. Fig. 14 shows the circuit featured in this project, and it employs three stages, an FET oscillator followed by two Class-A buffer-amplifiers. The Vackar circuit has been available in the literature for over a decade, but surprisingly, has received little use in practical applications. It is interesting to note that the Heath HW-8 oscillator employs the circuit. It is a quite stable configuration, and if reasonable care is exercised in p.c. board layout, parts selection, and mounting, a 100 Hz drift rate is attainable without difficulty. Frequency stability depends primarily upon the thermal, mechanical and electrical stability of the components used in the frequency determining part of the circuit at L1/C1-5, and the proper operating point for Q1. Polystyrene capacitors are used due to their excellent thermal performance although silver micas or tantalum types will be adequate. A pair of mounting holes for the addition of a temperature compensating capacitor at C3 (NPO or N750 disc ceramic) has been provided on the p.c. board in case the builder wishes to further compensate for thermal drift.

In the Vackar circuit, the frequency determining circuitry is connected in the drain-gate feedback path, with very light capacitive coupling to the gate. A variable capacitor or varactor tuning diode may be inserted at either the drain or gate end of the tuned circuit to provide desired bandspread. The optional p.c. board template in Fig. 15 includes provision for use of the varactor diode tuning system, while the p.c. board in Fig. 16 is intended for use with a variable capacitor. In either version, C4a (.001mF) with its extremely low reactance, allows the full capacitance represented by C4b-c or VR1-C4c (varactor circuit) to be placed across the frequency determining circuitry. If an air variable is on hand that is larger than the 34pF (80 meters) or 20pF (40 meters) sizes suggested, the value of C4a can be decreased to offset a higher value at C4b. In this case, C4c must also be increased proportionately to the increase in C4b. L1 is wound on a toroid core in this version of the circuit. However, an Amidon shielded slug-tuned toroid can be substituted. If it is, the slug permits tuning the circuit to the desired frequency, and C4b is unnecessary. For 80-40 meters, the Amidon L-43-2 is best, while the L-43-6 can be used for 30-20 meters. In experimenting with the circuit, the optimum C1:C2 reactance ratio was found to be about 3:5. The coupling capacitor at C5 can be as low as a few pF without affecting the operation of the circuit, although its size must be taken into account in determining the resonant frequency of the oscillator circuit. D1 limits the r.f. peaks appearing at the gate of Q1 and stabilizes the heat generated in Q1. Standard practice for achieving stability and interstage isolation has been followed in the design. RFC1-C7-R3 isolate the oscillator from any r.f. that might appear on the B+ line from Q2-Q3. Voltage regulation, essential to frequency stability in a v.f.o., is provided by the B+ dropping resistor R3 and a 1/2-watt, 6.1 volt zener diode (D2). RFC1 is a ferrite bead slipped over the drain lead of Q1 to discourage harmonics in the v.h.f. range (wax-mount it). Finally, r.f. output is taken from the oscillator across a 100-Ohms resistor at the source of Q1. The Vackar circuit has an advantage in that output can be had at this point, which is not in the loop comprised of the frequency determining circuitry. Hence, the oscillator is relatively immune to "pulling" by variations in the load presented by later stages. The relatively high input impedance of Q2 appears in parallel with the 100-Ohms source resistor (R2) and represents an r.f. path for a negligible portion of Q1 drain-source current. Q1 is coupled to the base of Q2 through a 150pF silver mica capacitor. Its reactance is added to the input impedance of Q2 as part of the load seen by the source of Q1. In the unit shown, oscillator "pull" was less than 50 Hz from open circuit to direct short of the output from Q3.

The oscillator output is isolated and amplified by Class-A buffer-amplifier stages at Q2 and Q3. The operating points of Q2 and Q3 are established by the ratio of base voltage divider resistors (R4-5, and R8-9) in conjunction with collector-emitter voltages. The absolute values of the resistors limit the maximum

Fig. 14. Single-Band Vackar V.F.O. with Optional Varactor Diode Tuning.



RFC1 - Amidon FB-73-101 bead

on drain lead of Q1

RFC2 - 21t., #28, FB-73-801
Amidon bead.

RFC3 - 7t., #21, FB-73-801

RFC4 - 25t., #28, FB-43-2401

C4b - air variable (see text)
C4c - 5-20pF N330 ceramic
trimmer (Johnson #275-
0320-005)

C3 - see text

D2 - 6.1v zener, 1/2-w, 1N753

VR1 - 33pF varactor tuning
diode (R-2503 or MV2109)

Q1 - MPF102

Q2 - MPS6514

Q3 - MPS6514

C3 - see text

A11 .01 - disc ceramic capacitors
Miniature p.c. board uses 1/4-w
resistors

Band: 80 40 30 20

C1 435pF 270pF 220pF 180pF

C2 1000 470 330 270

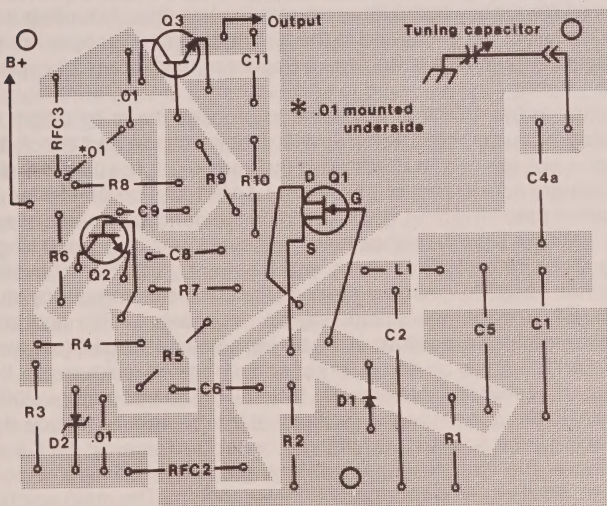
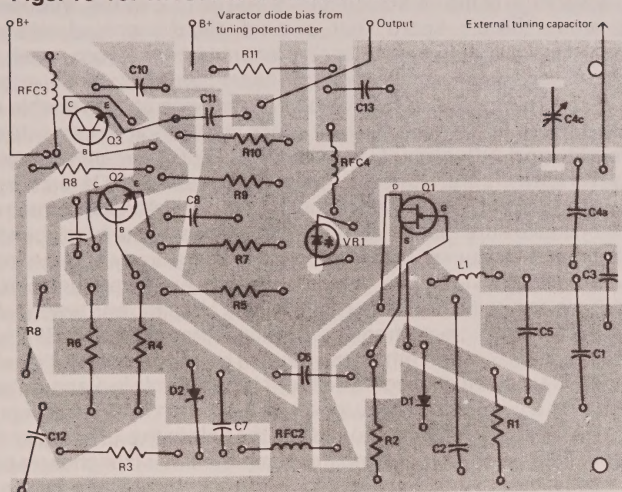
L1* 32t #32 21t #22 16t #22 13t #22

*wound on Amidon T-68-2 toroid core

base-emitter currents allowed to flow, and hence, thermal buildup. Q3 is an emitter follower with output taken across R10. The low input impedance of the stage driven by Q3 (transmitter input stage) appears in parallel with R10 (1k). This impedance is multiplied by the gain figure of Q3 to establish Q3's base input impedance. The reactance of C9 raises that further to arrive at a high input impedance which is presented as the load to Q2. This produces very good isolation from the load presented to the Q3. Output from the v.f.o. is on the order of 2 volts r.m.s. (across 1k-Ohms) depending on supply voltage (12-13.6v). R.m.s. voltage readings are presented in Fig. 14 (40 meters): those shown for the ends of L1 can be expected to vary widely from unit to unit. However, Q2-Q3 readings should be close. The unit easily drives the Viking-5 to full output.

(2) P.C. Boards. Figs. 15-16 show optional p.c. board designs for construction of the Vackar v.f.o. Fig. 16 is a miniaturized version intended for use with the singleband Viking-5. It uses 1/4-watt resistors and is a fairly high-density layout. This version and the singleband Viking-5 will fit snugly into a Calctro #101 chassis box (see "Parts Sources", Circuit Specialists) measuring 1.25 x 2.25 x 4.25 inches to produce an ultra-miniature 5-watt transmitter. In this version, an air variable capacitor is used for frequency tuning and, due to the limited space in the box, it is not possible to install a vernier drive. However, one is not essential in a transmitter, since the fine tuning required in a receiver is not as important in transmitter frequency spotting. A Johnson "panel mount" air variable with maximum capacity of 34pF (Johnson #193-0010-001) will produce a bandspread of about

Figs. 15-16. V.F.O. Parts Placement.



120 KHz on 80 meters, and a 20pF size (Johnson #193-0006-001) will provide about 110 KHz on 40 meters (see Circuit Specialists). C4a may be varied to adjust the amount of bandspread provided by a given size variable capacitor, or it may be omitted if the variable alone provides the desired bandspread. Of course, the unit may be placed in a larger enclosure if desired and a vernier drive installed. If the unit is combined with the Viking-5, the only extra precaution needed is to place a metal shield between v.f.o. and transmitter (or a piece of p.c. board cut to size and grounded). Even though the PI-network filters in the Viking-5 are wound on toroids which concentrate the r.f. field within the core, they and associated r.f. output leads can still generate a sufficient r.f. field to couple into L1 and cause frequency "pull".

Fig. 15 is a larger version of the p.c. board which uses 1/2-watt resistors and includes provision for a varactor diode tuning circuit as shown in Fig. 14. If the

varactor diode circuit is used, C4c (variable) and its associated C4a-b are eliminated. The advantage of the varactor circuit is that all r.f. bearing, frequency sensitive leads are on the p.c. board itself, and only the d.c. control voltage leads leave the board to the tuning potentiometer mounted on the front panel. Hence, the mechanical instabilities resulting from off-board frequency sensitive leads are eliminated. The larger layout of Fig. 15 can be used with an air variable as well. Either board is made from single-clad p.c. stock (copper foil on one side only).

(3) Assembly and Adjustment. Installation of Q2-Q3 circuitry is non-critical and requires no special care. However, this is not the case with Q1 circuitry. Some comments will be helpful. First, when mounting the oscillator polystyrene capacitors (C1-2-3-5), make sure that the ground foils, shown by the black band at one end, are connected to ground. Pull the capacitor leads firmly into the mounting holes. Otherwise, slight jarring will shake them and cause frequency instability. Next, RFC1-2 are part of the frequency determining circuitry, and any mechanical instability at RFC1-2 will cause frequency shifts. After mounting RFC1-2, wax from a birthday cake candle (or other type) should be flowed over all the windings of RFC2 and RFC1 onto the p.c. board so that it is held firmly in place. To assure a rigid mounting for L1, a 1/2-inch 4-40 screw with 1/2-inch fiber washer (cut from p.c. stock) is inserted through the L1 toroid into the hole in the p.c. board and bolted firmly in place. Finally, when mounting the completed unit in a chassis box, use two or three equal length metal spacers to establish a level plane for the board. Warp and frequency instability can result when four mounting screws are used. The lead from the p.c. board to the air variable tuning capacitor should be relatively heavy gauge wire to achieve a degree of rigidity — #18 copper is adequate.

In assembling the unit, it is advisable to proceed stage by stage. Once the oscillator stage is assembled, hook up the supply voltage and check for oscillation — if an r.f. voltage can be detected at the ends of L1, the circuit is oscillating. Next, preliminary adjustment of L1-C4c or L1-VR1 can be attempted. With the station receiver tuned to about 100 KHz inside the band, compress or spread the turns of L1 until the signal swishes past on the receiver, and then bring it on frequency by more careful adjustment. If a frequency counter is available, the receiver is not needed — simply readout the oscillator frequency during this adjustment. Some experimentation may be necessary in this first adjustment step due to variations in the values of the tuning capacitor and L1 (everyone winds toroids differently!) It may be necessary to add or remove one turn at L1 (one turn yields a frequency shift of approximately 100-150 KHz on 80 meters, 200-400 KHz on 40 meters) in order to place the oscillator at the desired frequency. It also may be necessary to substitute slightly different capacitor values at the C1 end of L1. As noted above, the r.m.s. voltages appearing at L1 can show a wide variation from those noted in Fig. 14 without indicating a problem. The main point is that the stage is oscillating. Once Q1 is operating properly, assemble the Q2 stage, but mount R4 temporarily. Apply power and check the r.m.s. voltage at the collector of Q2. It should approximate the reading shown in Fig. 14. If it is 0.5v lower than the voltage shown, determine the value of R4 that produces the highest reading by substituting resistors in the 15k-27k-Ohms range. Next, assemble the Q3 stage and temporarily connect a 1000-Ohms load resistor across the output terminal. Apply voltage and measure the output developed across the load resistor. Output should be above 1.7 volts r.m.s. If it is below that, experiment with values of R8 until peak output is achieved. Once the unit is functioning properly, it is ready for installation and final adjustment.

With the sub-miniature v.f.o. (Fig. 16) installed in its enclosure and the air variable tuning capacitor connected, readjustment of L1 and perhaps C1 will be necessary. With the plates of the variable fully meshed (maximum capacitance), compress or spread the turns of L1 until the signal is located at the bottom edge of

the desired frequency range. If the board of Fig. 15 is used, trimmer capacitor C4b is adjusted to place the oscillator at the bottom end of its range. Next measure the amount of bandsread available. If too much, decrease the value of C4a until the proper bandsread is achieved. One trick that can be applied with a sharp pair of clipper-pliers is to simply clip small pieces from the disc ceramic C4a. The only problem is that this sometimes results in shorting the plates of C4a. Once the desired bandsread is obtained, the unit is ready for operation. If higher temperature stability is desired, temperature compensating capacitors (N.P.O., N750 disc ceramics) can be substituted at C3 and/or C1 until the best drift vs temperature variation is obtained. This is tedious work and usually unnecessary.

(4) Varactor Tuning System. The p.c. board of Fig. 15 includes provision for a varactor diode tuning circuit. Fig. 14 shows this circuit, which is connected into the circuit at the points indicated by arrows. The 25k-Ohms frequency tuning potentiometer and 2k-Ohms resistor are mounted off-board on the front panel. The tuning voltage is taken from the zener regulated voltage at the point shown in order to enhance stability. Maximum junction capacitance of the varactor diode occurs with minimum reverse bias (i.e., 25k-Ohms tuning pot set to place maximum resistance between the B+ lead and R12 and lowest voltage on VR1). With the varactor circuit, the size of L1 should be decreased by 1-2 turns, determined experimentally. With the values shown, 80 meter bandsread is about 120 KHz. For 40 meters operation, C4a should be decreased to about 270pF to provide about 120 KHz bandsread with the R-2503 or MV2109 diodes listed. The tuning potentiometer should be of the linear taper variety.

(5) Driving the Viking-5. Interfacing the two units is done simply by connecting the output of the v.f.o. to the base of Q1 in the Viking-5. BEFORE ATTEMPTING TO OPERATE THE V.F.O. AND VIKING-5 TOGETHER, THE .001mF CAPACITOR BETWEEN Q1 EMITTER AND BASE (VIKING-5) MUST BE REMOVED. Once the units are installed and connected, apply power and key the Viking-5 and note r.f. output. Then adjust C1b (Viking-5) for maximum output while monitoring on the station receiver. Note the amount of shift in the v.f.o. frequency during keying. If the v.f.o. and transmitter boards are separated by a metal shield, minimal shift should occur, if any at all. Note the amount of shift while adjusting C1b through the maximum output setting and adjust for minimum shift. Once this adjustment is completed, commence making QRP contacts. One further note about using the units together is in order. The bandwidth of the Viking-5 PI-network output filter and Q1 tank circuit is narrower on 80 and 40 meters than the 120 KHz bandsread of the v.f.o. Hence, the rig will exhibit a drop-off in r.f. output at both ends of the v.f.o. frequency range. It will not be a significant drop-off though. However, if for some reason constant output is desired across the entire range, Viking-5 trimmer C1b can be replaced by a panel mounted variable to permit peaking the Q1 tank across the band. Overall, the combined v.f.o. and Viking-5 produce a healthy 5-watts output with excellent keying and little pull. The rig is a great 2-3 weekend project for those weekend trips when a miniature rig is desirable!

VI. Twoband V.F.O. for the Viking-5

Once the Viking-5 basic circuit was extended to the twoband version, the logical step was to go ahead and design a twoband v.f.o. capable of driving the Viking-5 on both bands. This section describes just such a v.f.o. designed specifically with the Viking-5 as its companion transmitter. It features switchable high output on both 80 and 40 meters. The unit has not been retooled for the other harmonic band combinations that are possible. However, the frequency doubler-driver circuit has been used in other transmitters up to 28 MHz, so it can be done. The p.c. board design makes little attempt at miniaturization, so that the project is

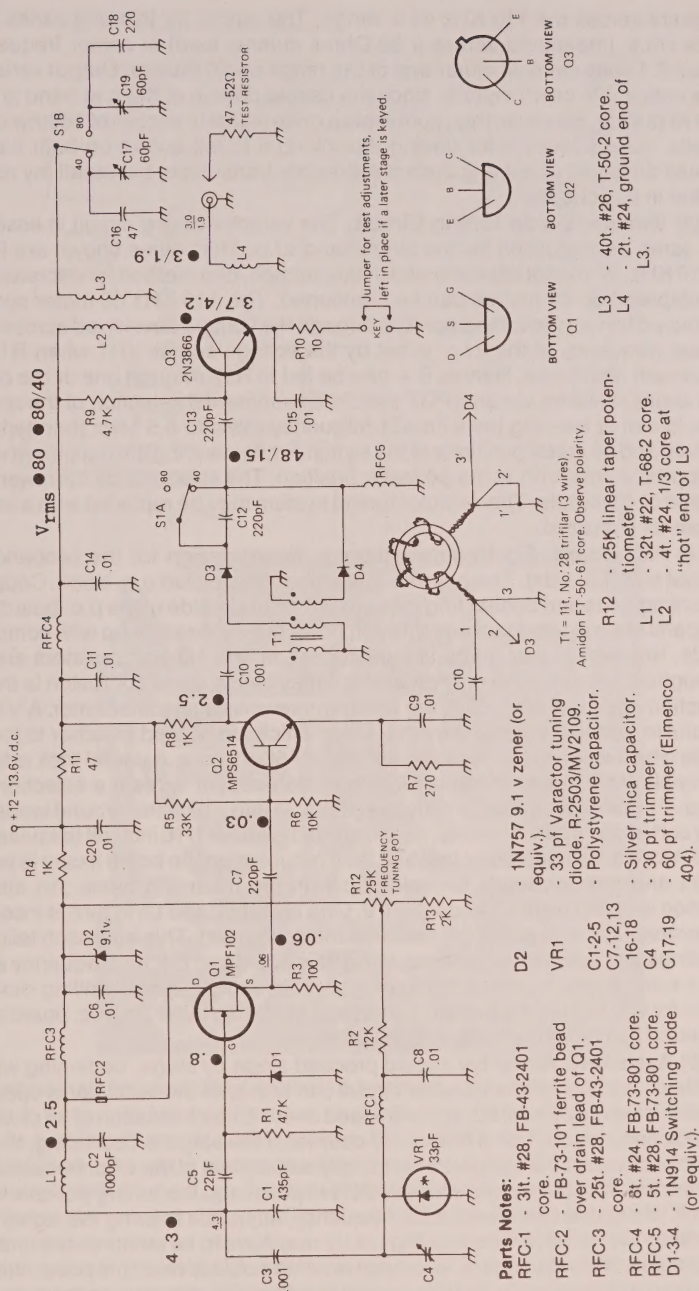
within the reach of the beginner, as is the case with the Viking-5. It presents more of a challenge than the v.f.o. discussed in the previous section, but permits an opportunity to learn about new construction techniques and circuits.

(1) Vackar V.F.O. Circuit. Fig. 17 shows the circuit of the twoband v.f.o. The oscillator employs the same circuit as the oneband v.f.o., but the similarities stop there. The oscillator operates on 3.5 MHz for both bands, with that signal doubled to 7 MHz for 40 meter operation. The values shown in Fig. 17 provide about 110 KHz bandspread on 80 meters (220 KHz on 40 meters), a compromise figure. 40 meter bandspread is twice that obtained on 80, a result of the frequency doubling process used to generate the 40 meter signal. If 40-20 meter operation is desired, the values of the frequency determining components L1/C1-2-3-5 should be scaled down (i.e., 7 MHz values chosen to exhibit the same reactance as the 3.5 MHz values — see **ARRL Handbook** for formulae). C3 should be about 270pF to provide 110 KHz spread with the oscillator on 7 MHz (40-20 meter operation). The tank circuit at Q3 would require scaling as well. For the most part, the functions of the various components of Q1-Q2 are the same as for the circuit of Fig. 14, and further comment is unnecessary. Q2 is a standard Class-A buffer-amplifier here also, but it and Q3 are further isolated from Q1 by R11-C11. Output from the collector here is fed to a passive diode doubler circuit, instead of to a second buffer amplifier. Q2 provides about 2.5 volts r.m.s. at the input of the doubler, a level needed to offset the loss through the passive doubler.

(2) Diode Doubler, Output Amplifier. Twoband operation is made possible through the use of the passive diode frequency doubler consisting of T1-D3-D4-C12-RFC5. Operation of the doubler can best be explained by analogy with the familiar power supply full-wave rectifier circuit (see **ARRL Handbook**), where T1 is analogous to the center-tapped power transformer, D3-4 to the rectifier diodes, and RFC5 to the filter capacitor. In the power supply application, each diode permits passage of the a.c. current during one-half of the cycle, but because of the phase reversal occurring due to the center-tap of the transformer, both positive and negative swings of the input voltage appear on the positive side of the waveform zero line in the output. This “humpback” a.c. voltage charges the filter capacitor to the peak value of the a.c. voltage swing, and the capacitor maintains a roughly constant d.c. output voltage. Now, in the frequency doubling circuit of Fig. 17, T1 provides the necessary phase reversal, and both positive and negative swings of the oscillator voltage are added in the output from the diodes, resulting in an output signal twice the frequency of the input signal. However, since r.f. output is desired, RFC5 is substituted for the filter capacitor of the power supply circuit. It provides a d.c. path for currents flowing in T1-D3-D4, but presents a high reactance to the r.f. output of the diodes. The only r.f. path presented to the r.f. output from the diodes is through the base-emitter junction of Q3. The doubling process can be defeated by the insertion of C12, which breaks the d.c. current path along T1-D3-RFC5 to ground. Then only the r.f. output from T1-D4 appears at the base of Q3, and its frequency is the same as the signal input to the doubler. So, the doubler circuit can be left in the circuit for both fundamental and second harmonic operation. Note from r.m.s. readings in Fig. 17 that 80 meter output from the unbalanced doubler is still considerably higher than on 40 meters. Incidentally, one discovery from working with the circuit is of interest: T1 enhances inter-stage isolation considerably, minimizing the effects upon the oscillator of variations in the load presented to Q3.

Output amplifier stage Q3 is operated in Class-B to avoid the harmonic content which characterizes Class-C operation, while at the same time providing reasonable gain and efficiency. Proper biasing of the stage is important in order to maintain signal purity, and it was found that R9 in combination with a small amount of emitter degeneration (R10) were adequate. Unwanted signals are below desired output signal by a quite acceptable margin. The tank circuit (L2-3-4) used at the

Fig. 17. Two-Band Vackar V.F.O.



output of Q3 is the same type as discussed for the Viking-5 (L1-2-3). S1b inserts the proper capacitance across L3 to resonate the stage either on 80 or 40 meters. As with the output from the Viking-5 Q1 tank circuit, a variation in output from Q3

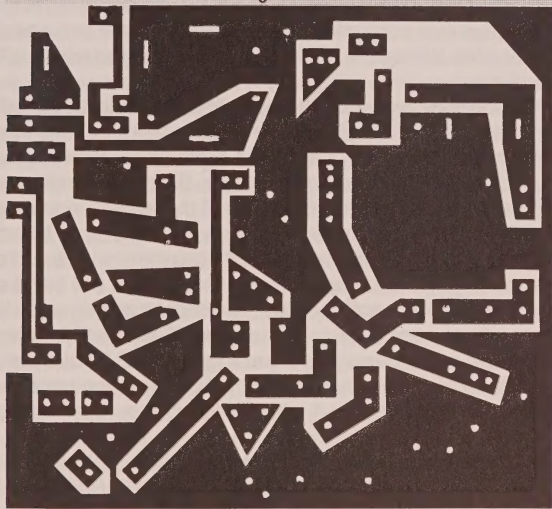
appears across the 110 KHz v.f.o. range. The output for this unit varies from 3 volts r.m.s. (measured across a 50-Ohms dummy load) at center frequency to about 2.1 volts r.m.s. at either end of the range on 80 meters. Output variation is less noticeable on 40 meters, since the usable portion of the c.w. band is hardly 100 KHz wide. However, this represents a drive signal in excess of 100mw on both bands, quite adequate for driving the Viking-5 to full output on both bands. It should drive just about any decent solid-state transmitter, but recall my remarks earlier in this chapter!

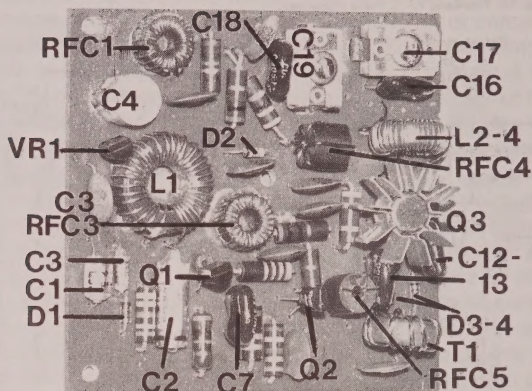
(3) Varactor Diode Tuning Circuit. The varactor tuning circuit is essentially the same as discussed for the singleband v.f.o. The values shown are for 3.5-3.610 KHz. While not implemented in this version, one method for decreasing the bandspread on 40 meters can be mentioned. The 110 KHz 80 meter spread is produced by varying tuning pot R12 through the voltage developed across it. The lowest frequency of the v.f.o. is set by the voltage across VR1 when R12 is at maximum resistance. Hence, B+ can be fed to R12 through one or the other of two series resistors via an SPDT switch. Experimental selection of the resistors should aim at keeping the v.f.o. Q1 frequency close to 3.5 MHz (bandedge) for both 80 and 40 meter positions of the switch, while lowering the maximum voltage to appear across VR1 in the 40 meter position. The effect will be narrower bandspread of 40 meters. The varactor tuning system may be replaced with a variable capacitor if desired.

(4) P.C. Board. Fig.18 shows the p.c. board design for the twoband v.f.o. (actual size, foil side). The board is made from single-clad p.c. stock. Copper foil mounting pads and connecting foils are on the underside of the p.c. board, while the parts are mounted top-side through holes drilled to match up with component leads. No attempt was made at miniaturization and 1/2-watt resistors are used throughout. Perhaps the only area which may cause some confusion is the construction and mounting of T1, the trifilar (three windings) transformer. A VTVM is helpful in keeping track of the three wires which are twisted together to form the cable which is wound around the Amidon FT-50-61 core. A useful trick is to wind the cable from three different color enameled copper wires if a selection is on hand. T1 then is mounted directly over the hole into which the ground leads fit — they sort of serve as a pedestal, and the toroid is about 1/16 inch off the board. The L2-3-4 toroid may be wound first and then mounted on the board if care is taken to orient and trim the leads to match up with the mounting holes. An alternate method is to first wind L3 and mount it. One end of L2 and L4 in turn is inserted in the proper hole and soldered, and then the coil wound. This approach tailors the windings and leads to suit the mounting hole positions. C4, the frequency adjustment trimmer, may be of a different type than shown; before drilling mounting holes for C4, be sure they match up with C4 mounting tabs. The p.c. board can be prepared using the methods suggested earlier.

(5) Assembly. Assembly should proceed stage by stage, beginning with the oscillator. Addition of the Varactor circuit can wait until the oscillator is operating. Once the oscillator is wired, apply B+ and check L1 for indication of an r.f. voltage or frequency readout on a frequency counter. If the stage is oscillating, then the Varactor circuit can be added. Preliminary adjustment of the v.f.o. frequency can be performed once the Varactor circuit is in place and the tuning pot connected. With R12 adjusted for lowest v.f.o. frequency, adjust C4 to bring the signal to the bandedge at 3.5 MHz. The windings of L1 may have to be compressed or spread to complete this adjustment. Accuracy is not the objective at this point. Next, the Q2 stage and frequency doubler can be installed. R5 determines the gain of the buffer stage and the value shown should produce peak gain. However, one transistor tried in the circuit (not an MPS6514) required an R5 value of about 50% of that shown (recall earlier notes on substituting transistors in a circuit). R.m.s. readings can be checked against those shown in Fig.17 and should be close. Q3

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tored, and C17 adjusted for a minimum. Then the 20 meter harmonic checked vs C17 settings. The signal at 10.5 MHz can also be checked if a general coverage receiver is available. The objective is to adjust C17 for maximum 40 meter output accompanied by minimum 80 and 20 meter output. If these conditions do not occur at the same C17 setting, the position of L2 can be varied to improve matters. While the objective is to achieve the purest output waveform possible, it need not be perfect, since the Viking-5 adds two stages of filtering which will suppress harmonics effectively.

Final adjustment of the v.f.o. should follow procedures noted for the single-band v.f.o. Adjustment of C4 should be adequate for setting the bandedge frequency. Otherwise, compress or spread L1 windings. See earlier comments for obtaining narrower bandspread on 40 meters. Birthday candle wax is flowed over L1 and RFC1-2-3 to insure rigid mounting of these frequency sensitive components. Once the oscillator is adjusted to provide the proper bandspread, repeat the peaking of Q3, C17 (40 meters), and C19 (80 meters) at band center. Note the band center readings, and compare to the readings at the band edges. This will provide an indication of droppoff in output at either band edge. On the units tested, band center readings were 3 volts r.m.s. across 50-Ohms (80 meters) and 2.1 volts r.m.s. (40 meters), while band edge readings were 2.2 volts r.m.s. (80) and 1.7 volts r.m.s. (40). Incidentally, the twoband v.f.o. has been used to drive an MPS-U31 in a Class-C amplifier circuit with PI-network output filter to about 3 watts output.

(6) Driving the Viking-5. Comments about the singleband v.f.o. apply here as well. DISCONNECT THE .001 FEEDBACK CAPACITOR BETWEEN BASE AND EMITTER OF Q1 (VIKING-5). Solder a jumper wire across the key terminals of Q3 — the v.f.o. runs constantly while the Viking-5 is keyed. With both v.f.o. and Viking-5 on 80 meter center frequency, apply power and key the Viking-5 while adjusting the Viking-5 Q1 80 meter trimmer C1b for maximum output from the transmitter. Repeat the process on 40 meters. The loading effect of the Viking-5 may slightly detune the v.f.o. Q3 tank circuit, so readjust C17 and C19 on the respective bands as noted earlier. Comparing the Viking-5 r.f. output at bandedges with center frequencies will show the droppoff noted for both Viking-5 and v.f.o. A more linear output curve can be obtained by stagger tuning the v.f.o. amplifier and Viking-5 driver. The v.f.o. output is peaked at 30% above the lower band edge, while the Viking-5 driver (Q1) is peaked at 30% below the upper band edge. A more uniform output across the band results. My personal preference is to peak both on the QRP calling frequencies (3060 KHz, 7040 KHz) and take what comes on the rest of the band. Keying the Viking-5 should produce no noticeable

shift in v.f.o. frequency. Q1 oscillates continuously during operation. Hence, it is necessary to remove the jumper across the v.f.o. key terminals, and substitute a T-R switch to switch the v.f.o. amplifier Q3 off during receive periods — otherwise, its signal may interfere with reception of incoming signals. If the v.f.o. is to be used as the local oscillator for a companion direct conversion receiver, transmit offset can be achieved by connecting a 50k-Ohms trimmer potentiometer between the R12-R13 junction and the key end of R10. While monitoring the signal on a receiver (or frequency counter), the trimmer resistance is slowly decreased until the desired offset occurs between key-up key-down periods. Once all adjustments are completed, the unit is ready to go on the air in search of WAS-QRP or DX! The Viking-5's 5-watt signal to a dipole at 50 ft. puts both within reach!

VII. High-Current Regulated D.C. Power Supply

Almost a dozen years ago, I described a high-current regulated power supply (**The Milliwatt**, June, 1973) which provided in excess of 4 amps output at 7-22 volts using the relatively new NE550A regulator chip. The unit required 12 components, in addition to the regulator and transformer-rectifier. Since then, the design and fabrication of IC voltage regulators chips has increased both in sophistication and power handling capacity. It is possible today to construct a d.c. power supply using one of the new IC regulators and just two external components which set the output voltage level, plus, of course, the transformer, rectifier and filter capacitor. Output currents of up to 5 amps are possible with excellent load regulations of under 1%! Just a decade ago, a long list of components plus complicated design procedures were necessary to construct a supply which included all of the circuitry found on a single IC chip such as the LM317 and LM350. With devices such as these, design and construction are a breeze! **LM317/LM350 IC Regulators.** The secret to simplification of design and construction is the fact that all of the components formerly found in a discrete supply circuit are mounted on the IC chip itself, including the high-current carrying series pass element transistors. The LM350, for example, includes 26 transistors, 1 FET, 3 zener diodes, 26 resistors and 3 capacitors on a single chip! Since the devices are intended as adjustable output regulators, the two resistors which set the output voltage are not included on the chip, but left to the choice of the designer. However, other regulator types which are designed to provide a fixed output voltage include these resistors on the chip. In addition to the basic regulating functions such as generating a reference voltage, error sampling and amplification, and series pass element amplification, the LM317 and LM350 include a current limit circuit which internally limits short-circuit levels to 2.5 and 4.5 amps respectively, a thermal overload protection circuit which limits dissipation to rated levels, and a safe-area protection circuit for the series pass element transistors. All overload circuits remain fully functional even if the voltage adjustment circuit is disconnected, resulting in virtually indestructible devices. In addition, all devices are "burned in" during manufacture, guaranteeing that the internal protection circuit functions to rated specifications. The two IC's discussed here are capable of producing a regulated output over the range of 1.2-33 volts and require a minimum input/output differential of 3 volts. While specs indicate a maximum input voltage of about 35 volts, the devices have functioned properly with over 40 volts input. In practical terms, this means that any transformer capable of producing up to 25 volts to a full-wave bridge rectifier can be used with the IC's.

(1) Design Considerations.

(A) Device Selection. The selection of the IC regulator depends upon the voltage and current requirements of the supply. The LM317K seems to be greatly under-rated at 1.5 amps output current. The device tested here was capable of just over 2 amps output with 0.4% regulation (12,000mF filter capacitor). How-

ever, this device may exhibit maximum specs, while others may fall into the center of the range (typical rating). On the other hand, the LM350 showed an absolute maximum output of 3.1 amps. It was impossible to raise this current level while maintaining less than 1% regulation. Both devices exhibit the same maximum input voltage and input/output voltage differential requirement of 3 volts. The LM350 spec sheet suggests that one should be able to expect close to 4 amps output at full regulation. This example may be atypical.

(B) Transformer Selection. The volt-amp (VA) rating of the transformer should provide at least 3 volts output from the filter capacitor more than the desired maximum output from the regulator. That is, if the supply is supposed to provide a maximum of 15 volts output, input voltage from the capacitor must be a minimum of 18 volts. For a full wave bridge rectifier circuit, output from the transformer, rectifier and capacitor circuit to the IC regulator input will fall between 1.35-1.65 times the transformer rating across the entire secondary winding. The actual output voltage will depend upon internal characteristics of the transformer itself. The above 1.35-1.65 factor is the result of measurements for various transformers feeding the rest of the circuit, with a 220-Ohms load across the output of the supply. Secondly, the current rating of the transformer should provide, at minimum, the desired supply output current requirement. However, there is a considerable variation in output from equally rated transformers. High quality units usually exceed the stated current rating, while bargain types usually fall below it (tip — never use a Radio Shack transformer). A general rule of thumb is to select a transformer with a current rating of about 30-40% higher than needed. This is especially true if the supply is to power a load which exhibits wide variations in current requirements, such as is the case with a c.w. or s.s.b. transmitter, where current may fluctuate between 0.12 and 2.8 amps in key-up key-down shifts. The excessive current rating will permit damping of the transient responses due both to input voltage variations and output current variations as the current load swings between minimum and maximum. An IC regulator, as well as any regulator, requires finite time for error-sampling and output voltage correction, and although these functions are performed so rapidly that they cannot be detected on a meter, they occur nonetheless and can affect the load. For example, the LM350 transient response time for a 1 volt variation in output voltage is only about 2 microseconds, and about 6 microseconds for an output current variation of 1.5 amps. Input variations automatically occur because of transformer I^2R loss when current swings high. Placing a VTVM across the output from the filter capacitor and then keying the transmitter slowly will provide a sense of how this works. An IC regulator monitors the output voltage instead of the input voltage. The transient response time is the duration required for the IC regulator to sense and correct a variation in output voltage. It does this by controlling the gain of pass element amplifiers, which function basically as variable resistors. In a typical situation, such as noted above, a swing in output current from 0.12-2.8 amps will produce a drop in input voltage to the regulator of considerably more than 1v, depending upon the actual VA rating of the transformer, with the drop increasing as the maximum VA rating is approached. The higher the VA rating, then, the lower the input voltage variation under a given output current swing.

There is a compelling reason for using a transformer that exceeds the VA requirements of the supply when it is used with solid-state transmitters. The events that take place during the transient response time can have a disastrous effect upon solid-state amplifiers in several ways. First, the transient response may take the form of a voltage spike when going from key-down to key-up (voltage rises as current drops). This spike may exceed the junction breakdown ratings of the transistor, destroying it. When ballasted emitter devices are used, they are usually unaffected by spikes as far as junction damage is concerned — instead of a single emitter junction, they have a multitude and spread out the effects of a

TABLE for Estimating Heat Sink Size from θ_{SA} , C/W .

Size (Sq. in.)	Thickness		θ_{SA} , C/W					
	3/16"	3/32"						
1	6.8	6.5	15	3.5	4.2	35	2.62	3.07
5	6	6.1	20	3.1	3.7	40	2.55	2.9
8	4.8	5.1	25	2.9	3.45	45	2.42	2.75
10	4.2	4.7	30	2.75	3.25	50	2.35	2.65

(To use, calculate the thermal resistance-- θ_{SA} --required as per step 1.3 of Appendix 1. Find this thermal resistance in the proper thickness column above, then readout the necessary surface area in the "Size" column, given in "square inches." The table is for vertical fins only. Example: if θ_{SA} calculated to 4.6 C/W , and 3/16 inch stock is used, 4.6 C/W falls between 8-10 sq. in. Interpolate to about 9 sq. in.)

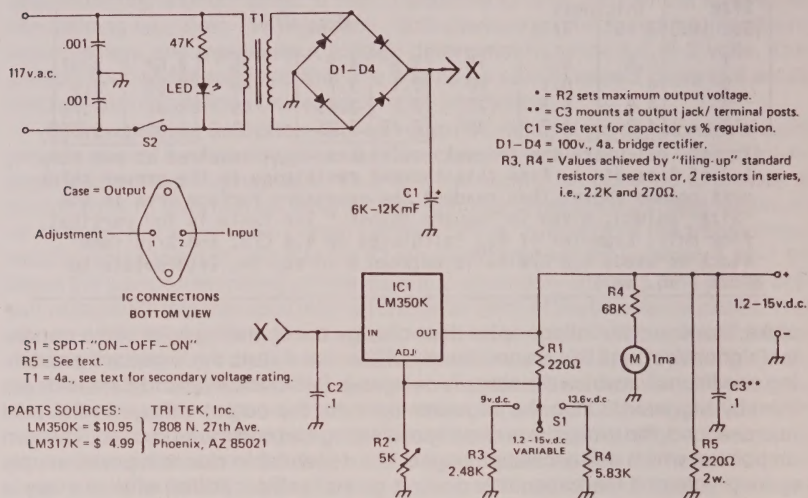
spike. However, the voltage spike does change the operating point of the transistor (higher V_{cc}), and this is sometimes sufficient to disturb the impedance matching conditions for which the stage is designed. Self-oscillation and parasitics are thereby triggered. Once the regulator corrects the output voltage in the next microsecond, the transistor is already oscillating and continues to do so. The turn on point at which self-oscillation begins is a dependable clue to a power supply spike problem. If the transmitter doesn't go into self-oscillation when the key is depressed and the signal, as monitored on a receiver, is a clean c.w. or s.s.b., but then breaks into self-oscillation when the key is released (hash noise appears and collector current sky-rockets), power supply spikes are causing the problem. Finally, if a relatively non-fluctuating load is anticipated, excellent regulation can be expected without the above precautions.

(C) Rectifier Circuit, Diodes. The full-wave rectifier circuit is preferable to the half-wave in high-current supplies. First, it provides maximum transformer utilization. Next, diode PIV (peak inverse voltage) rating requirement is half that required for equivalent half-wave and full-wave center-tap circuits. Finally, it provides a higher input peak voltage to output average voltage ratio, requires less filter capacitance, and produces a lower ripple figure. Full-wave bridge rectifiers are available in single package form and are quite economical.

(D) Filter Capacitor. The filter capacitor should be rated to handle the maximum surge voltage from the transformer. This is usually equivalent to a 1.4 factor. The size of the capacitor required to produce a given ripple figure can be calculated, but generally, low-current supplies (500ma and under) will exhibit good regulation with a filter capacitor of 1000mF or so. The size of the filter capacitor must be increased significantly to produce excellent regulation figures at high-current levels. In the units discussed here, the load regulation achieved under no-load 100ma to 3.0 amps full-load regulation for the following filter capacitors was: 6000mF = 1.06%; 8000mF = 0.8%; 10,000mF = 0.46%; 12,000mF = 0.39%, above which level no improvement was possible. An 0.1-1.0 amps swing shows 0.8% regulation with the 6000mF size.

(E) Heatsink Requirements. The power dissipation of the LM317K and LM350 is limited internally to safe levels — when junction thermal buildup reaches the danger point, the IC simply turns itself off. Even so, heat removal is necessary to maintain a fairly constant junction temperature so that best regulation can be obtained. This because internal thermal buildup affects both reference voltage and adjustment current with consequent effects upon output regulation. Junction-to-case thermal resistance θ_{jc} is the limiting factor, since it establishes the greatest amount of heat that the device itself can conduct from junction to case and thence to a heatsink. If the total junction-to-case thermal resistance θ_{jc} is too high for the heat to be dissipated, another device must be

Fig. 19. LM317K/LM350 Regulated Supply.



used instead (see Appendix). The major source of thermal buildup is in the flow of current through the series pass element transistors, which act as variable resistors to produce a controlled drop in voltage between input and output terminals. As noted above, the minimum input/output voltage differential for regulator operation is about 3 volts. At maximum 3 amps current, then, approximately 9 watts must be dissipated ($V \times I = W$, $3v \times 3a = 9w$). This amount usually can be handled by mounting the TO-3 package on a moderate size chassis box, although some heat-sinking is necessary to keep the device at the warm level in such a case. However, as the input-output ($V_{in} - V_{out}$) differential is increased at a given current level, power dissipation requirements increase proportionately. For example, given an input voltage to the regulator of 18 volts and an output of 5 volts, the differential is 13 volts, producing 39 watts dissipation ($13v \times 3a = 39w$). A large heatsink is required in this case.

So, in designing a fixed output voltage power supply, the transformer voltage rating (through the rectifier and filter capacitor) should be selected to produce slightly more than the 3 volts differential to the input of the regulator under full load. For example, suppose that a supply with a fixed output of 13.6 volts at 3 amps is desired. If an 18 volt transformer is used, input voltage to the regulator will be about 27 volts. This will produce an input/output differential of about 13 volts, and at 3 amps, a 39-watt dissipation requirement. But if we aim at an input voltage just above the 3 volt differential, an input of 16.8 volts suffices, and will produce a dissipation level of 9 watts. A 12 volt transformer will suffice. If a variable output supply is desired, the input voltage to the regulator must show the 3 volt differential at the highest output voltage. But note that, at the low end of the variable output range, the power dissipation requirements will be much greater than at the high end and require a large heatsink. In short, heatsinking can be minimized by selection of the transformer VA rating vs. fixed output level, but for a variable supply, this advantage is erased if high-current output is desired at the low end of the voltage range. A table is included in this section for estimating heatsink size in a given situation.

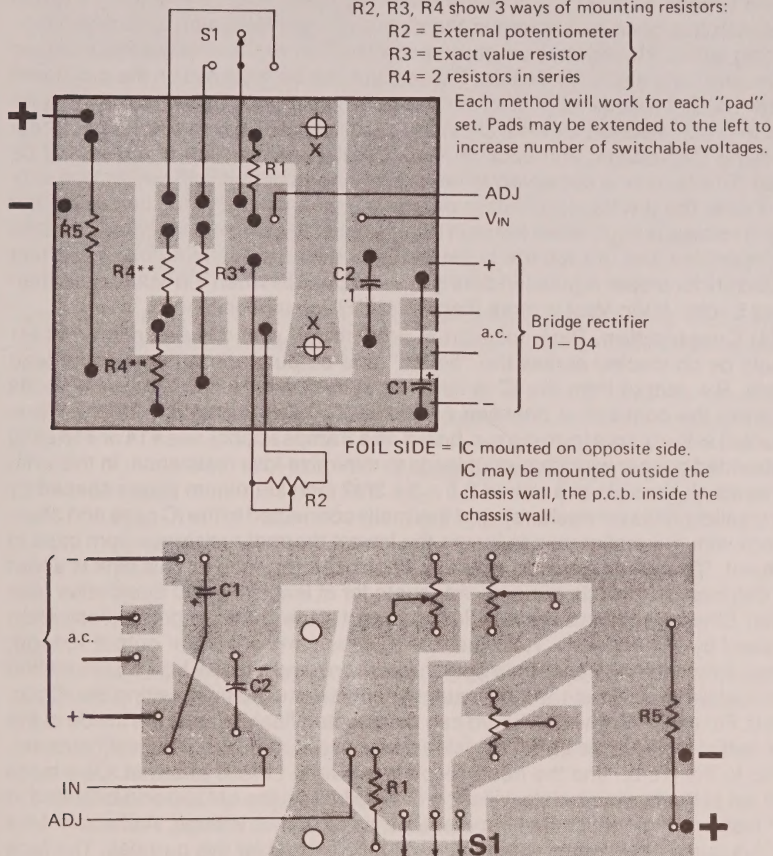
(3) Circuit Description. Fig. 19 shows the practical circuit of a power supply using either the LM317K (about 2.2 amps maximum) or the LM350 (3 amps maxi-

Fig. 20 Power Supply

R2, R3, R4 show 3 ways of mounting resistors:

- R2 = External potentiometer
- R3 = Exact value resistor
- R4 = 2 resistors in series

Each method will work for each "pad" set. Pads may be extended to the left to increase number of switchable voltages.



num for the device tested). An SPDT (on-off-on) switch is used to provide two fixed outputs of 13.6 and 9 volts, and variable output over the 1.2-15 volt range. A 12 volt, 4 amps transformer is used in combination with a 100v, 4a bridge rectifier package. C1, the filter capacitor, can be from 6000mF to 12,000mF for the regulation figures mentioned earlier. Input to the regulator from the circuit is about 18.2 volts. Other 12 volt transformers tried in the circuit produced inputs to the IC of 16.8-20.1 volts. With respect to the regulator circuit, R2 sets the output voltage level and forms a voltage divider with R1. A fixed output version would omit S1 and R3-4 from the circuit. In this version, R2 varies voltage across the 1.2-15 volts range with S1 in the off position. Maximum output voltage coincides with maximum R2 resistance. For fixed output voltages, R2 is set to maximum resistance, and S1 places either R3 or R4 in parallel with R2 to lower the total resistance between the IC "adjust" terminal and ground and establish the fixed output level. R2 can still be used to vary either fixed output downward. An alternative approach for any number of fixed outputs consists of switching the appropriate value resistor (replacing R2) into the circuit. Similarly, S1 and R3-4 can be omitted if fixed outputs are not wanted. The precise values of R3-4 can be obtained in two ways. First, the alternate p.c. board in Fig.20 permits mounting of p.c. trimmer potenti-

ometers for setting fixed output voltages. These are adjusted while monitoring output voltage on a VTVM until the exact regulated voltage results. A second approach has been mentioned in the discussion of attenuator construction — starting with a standard value carbon composition resistor below the required value, and filing it up to that value. The resistor can be mounted on the p.c. board and the output voltage monitored during the filing process. Or, the resistor may be filed in hand, inserted into the circuit by touching its leads to the proper pads, checking the voltage, and back to filing. Finally, the function of R5 should be noted. This resistor is necessary when the maximum output voltage from the supply is near the 3 volts input/output differential. In a no-load condition, regulator output voltage is high; when the load begins drawing current, the regulator snaps into operation and the voltage is lowered. R5 draws the minimum load current necessary for proper regulation during no-load periods when $V_{in}-V_{out}$ is less than about 5 volts. If $V_{in}-V_{out}$ is more than 5 volts, R5 is unnecessary.

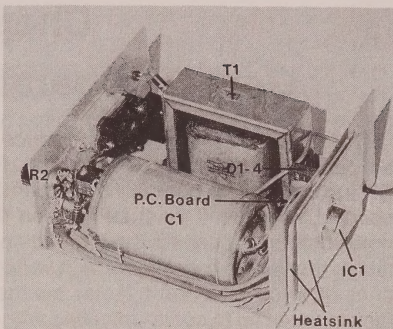
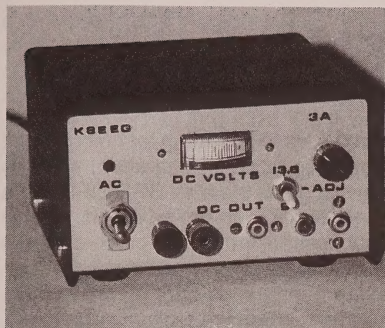
(4) Construction. Parts location is non-critical, with the exception that R1 should be connected across the “adjust” and output pads with minimum lead length. B+ output from the IC is taken from the case, and the mounting bolts establish the connection between case and “+” foil on the p.c. board. R5 is mounted at the output from the p.c. board. In a 3 amps supply, use #14 or #16 solid or stranded copper wire for output leads to minimize loss resistance. In this unit, the heatsink consists of a pair of 2.5 x 3 x 3/32 inch aluminum plates spaced by two smaller plates (or washers), and thermally connected to the IC case and chassis box with thermal grease to insure the lowest thermal resistance from case to ambient. Disregarding the chassis box, thermal resistance for this sink is about 4.5 degrees Centigrade per watt, adequate for at least 15 watts dissipation (see Table). Since the chassis box is included as part of the heatsink, power dissipation is raised by several watts. Note that the IC case carries the B+ output voltage; hence, it must be insulated from both the heatsink and chassis box. Mica or teflon shoulder washers (feed-through insulators) must be used in mounting the IC p.c. board. For example, the p.c. board can be mounted flush against the inside of the rear wall of the box, the LM350 outside the wall with “Vin” and “adjust” pins soldered to the p.c.b., and the heatsink plate between LM350 and wall. Or, a large hole cut in the heatsink plate will allow it to be laid on the LM350 and mounted in that fashion. Fig. 19 includes a meter to monitor output voltage. A cheapie 1ma surplus audio “VU” meter or similar can be converted for this purpose. The face cover is removed, and a self-adhesive address label stuck on as a new face, taking care not to damage the needle. A VTVM is used to set output voltages at one or two volt intervals, while a new dial scale is inscribed. The 68k-Ohms dropping resistor provides full-scale deflection at about 18 volts for this particular meter.

Appendix: Heatsink Calculations

The procedure for calculating heatsink dissipation requirements involves several steps, and the specs sheet for the IC regulator provides essential information about device characteristics for these calculations. (1) First, the $V_{in}-V_{out}$ differential is determined as noted earlier, and junction power dissipation (P_{diss}) at maximum output current ($P_{diss} = V_{in}-V_{out} \times I_{max}$). Then, the total junction to ambient thermal resistance required to maintain a selected junction temperature (T_j) at an expected ambient (room temperature T_a) is determined from:

$$\theta_{ja(total)} = (T_j - T_a)/P_{diss}$$

where $\theta_{ja(total)}$ is the largest thermal resistance that will conduct the P_{diss} heat from junction to room air. Generally, T_j is safe at 135C for silicon devices, and 85C



for germanium types. A T_a of 30°C is probably the maximum in normal situations. (2) θ_{jc} is the thermal resistance from junction to case, while θ_{ca} is the case to ambient thermal resistance.

(a) If $\theta_{ja}(\text{total})$ is greater than $\theta_{jc} + \theta_{ca}$ for the case type, no heatsink is required — the case itself is an adequate heatsink. θ_{jc} and θ_{ca} for standard cases are:

Case	In Degrees Centigrade per watt	
	θ_{jc}	θ_{ca}
TO-3	3-0.5 C/W	35 C/W
TO-220	3-8	50
TO-66	3-8	55
TO-8	4-9	75
TO-5	25-250	150

(b) If $\theta_{ja}(\text{total})$ is less than θ_{jc} , the device cannot handle the required level of dissipation. Select another IC device from the manufacturer's specs sheet which can.

(c) If $\theta_{ja}(\text{total})$ falls between θ_{jc} and θ_{ca} , the device can handle the power, but a heatsink is required.

(3) To determine the required thermal resistance of the heatsink (θ_{sa} , or heatsink to ambient thermal resistance), calculate:

$$\theta_{sa}(\text{C/W}) = \theta_{ja}(\text{total}) - (\theta_{jc} + \theta_{cs})$$

where θ_{cs} is case to sink thermal resistance. θ_{cs} for these:

Case	Thermal Grease	Thermal Grease/Mica Washer
TO-3	0.3-0.5 C/W	0.4-0.6 C/W
TO-220	0.6-0.8	0.8-1.1

Dry contact (no thermal grease) more than doubles these figures.

(4) Select an appropriate heatsink from mfr's specs in a supply house catalogue; or construct an adequate sink. The Table for estimating heatsink size found earlier in this chapter will suffice, or consult **RCA Power Circuits: D.C. to Microwave** (RCA, 1969), Fig.93, p. 82, for nomogram solution.

Chapter 6

General Operating Techniques

This chapter is intended to introduce newcomers to operating techniques that are useful in routine QRP operation. For specific types of operation, such as DX'ing, contesting, and working toward specific goals such as WAS-QRP, more specific techniques must be devised that are suitable to the situation. As I've noted before, patience is the foundation of successful operation, and that means taking the time to experiment with various techniques in order to establish which ones do and which don't. It also means taking the time to figure out how all the factors involved in communicating with low power influence a given situation — what does the other guy's signal reveal about propagation for the path, what does his fist or operating manner suggest about his ability or willingness to copy a weak signal, and other factors such as these. The QRP operator has to be a strategist who continually attempts to gain insight from every experience on the air. This involves learning what factors contributed to success when contact is made, and as important, what went wrong when no contact resulted from a call or string of calls.

For most of us, a lot of trial and error has been involved in evolving our operating habits. While this section should help eliminate some of the error for newcomers, sometimes it takes a bit of experimentation with the techniques described below to discover just how to translate the words into a successful strategy. For example, many veterans stress the importance of timing in making a call. Exactly what amount of timing delay before making the call is meant — 3 milliseconds, 20, 1 second? There is no absolute answer because each situation takes a specific amount of delay. In a DX situation, responding to a weak "CQ DX" from a DX station instantly after he signs is almost certain to blow a possible contact. Try to imagine what is going on at his end. He's just monitored his S9 sidetone oscillator (or his own voice on SSB), and he has to readjust his psychological level of perception before he is going to recognize the weak QRP signal calling him. Give him a second or so to readjust, and he is hearing everything the receiver is producing down to the noise level itself. When the weak QRP signal appears, he can distinguish it and mentally tune it in. Or take a second, rather frequent situation in DX'ing. An S6 PY1 or DL3 is calling "CQ DX" at about 30 wpm on a rather shaky 20 meter C.W. band. He repeats his call sign two or three times and then signs. I start calling him, but hear him resume CQ'ing before I've sent his call sign three times. Do I wait around and try again with his "K"? No, I'll forget him. He isn't listening or trying for real DX. His codespeed is the first clue, but the clincher is the short listening time between calls. The QRP operator can develop the sense of proper response only after a lot of experience, and that provides not only one of QRP's major challenges, but one of its major satisfactions. With a shiny new 200 watt rig, it is a simple matter to blunder to DXCC in a month, given a decent antenna and a couple hours per day operating time. But with QRP every call that is made can provide new insight into how to do it right. Every successful contact adds to that sense of accomplishment and growing confidence.

As noted in an earlier chapter, patience must be backed up by knowledge. Learning about antennas and propagation is a basic must so that realistic expectations govern the QRP operator's efforts. Operating techniques are not an isolated set of tricks designed to transform a dummy into a DXCC-QRP Trophy holder. Operating techniques will work only in combination with the knowledge of how antennas and propagation work in the practical operating situation. The QRP operator should know what to expect from his power output and antenna, in terms of distance and signal strength for the propagation path he is working and the

effect time of day, season, solar phase, and frequency will have on his prospects of success. Pick the wrong time of day or band, and no operating technique is going to do the trick. It all has to work together for success in QRP operation. Assuming, then, that you've done the homework on propagation and have an efficient antenna tied to the rig, the following points ought to get you started on the right path.

I. Calling Strategy

(1) Listen-Answer. First, one cardinal rule to follow is: don't waste time calling "CQ" with your QRP signal. Generally, other operators — either casual types or contest gunners — scan the band for easily copied signals. That usually means QRO signals, and not QRP! So, answer "CQ's" from other stations. After a while, signal reports will make it clear whether or not you'll ever find it advisable to call "CQ". Ten pages of log with mostly 559-569 RST's suggests that you avoid calling "CQ" ever. However, a fair number of 579-589 reports indicates that your system can put out the kind of signal another station will respond to. My own experience with a Gem-Quad (alas, dismantled for eight years now) showed that I could raise someone on 20 and 15 meters anytime I wanted to call "CQ". Even with a pair of phased verticals on my mobile home roof, most of the time a "CQ" will bring a reply. In fact, I've had the enviable experience of having QRO stations tail-gate my QSO's to compliment me on my signal, and frequently during QRP-ARCI Contests, my "CQ QRP TEST" calls have tempted QRO operators into giving me a contact. After the first four months of operation, a check of the log will provide a realistic picture. If the log shows that 85% of the successful contacts were with stations whose "CQ" you answered, and that signal reports were average or worse, just go on answering instead of calling "CQ". Avoid falling into the trap of calling a single station more than twice. If he hasn't answered your response after the second try, he is either not interested in working anything but an S9 signal, or his receiver gain is too low, or conditions are against you. After checking to insure that you've properly selected your calling frequency so that he can hear you, move on to another station (see below). You can assume that most other stations are running high power. You can usually spot another QRP station by his weak signal and his slow c.w. speed — one of the techniques. If a station calling "CQ" is weak or exhibits significant QSB (fading), it is very likely that propagation between your location and his is unpromising. Instead of calling him, move on and find another station.

(2) Identify as QRP. Since most knowledgeable operators use the above approach in judging propagation, it is important that you give an indication that you are a QRP station when you respond. The improper approach is by using the "/" as in W0RSP/QRP: it is to be used only to indicate that the station is operating at some location away from the address for which it is licensed. Instead of the slash, just leave a space or two — "de QRP W0RSP QRP W0RSP QRP" works well. I have found that the "de QRP" introduction usually is all it takes. The other station is psychologically prepared for a known prefix (W, KA, ZL, etc.), and no country uses the "QR —" prefix. The "de QRP —" doesn't fit and alerts his attention automatically. For the most part, other operators find it exciting to work a QRP station — if for no other reason than to find out exactly how much power the QRP station is running. And in order to find out, he'll have to increase his r.f. gain and start operating. I have had many very enjoyable contacts with curious QRO operators who kept me in QSO for 20-30 minutes for answers to their questions. Frequently, these QRO operators will tell me of their QRP exploits, i.e., the other QSO's they've had with other QRP stations! How's that for a twist? Actually, I find it really delightful when someone becomes excited about my interest, even though he's not part of the QRP group.

(3) Tail-Gating. Several other methods have been employed in making initial contact. One of these is tail-gating and it is very useful. Patiently wait for a station already in QSO with someone else to end the contact. If he hasn't signed with a "QRT" (closing down), call him as soon as the contact ends. It's a natural set-up. Since the contact has been going on for a while, other stations will usually have stayed away from the frequency. Once the contact ends, the QRP station has an "open" frequency for making the call. A second method that previously was considered acceptable was responding to a local (U.S.) station's "CQ DX" call. Technically, the QRP station is DX at the one-watt level, but he is **not** a foreign station. However, I hesitate to recommend this approach even though many U.S. DX'rs are more than pleased to respond to a QRP station in the U.S. instead of a QRO station in Italy. The potential problem is: with the massive increase in the number of QRP operators, if this becomes too frequent a practice, it could create a resentment among DX operators. A DX operator has put a lot of money into a good station for one reason — to work genuine foreign DX. He naturally wants to work DX. A QRP'r every now and then is enjoyable. Too often and it can become counter-productive. One qualification that will make the practice acceptable is for the QRP operator to wait several seconds to provide the DX'r time to search for weak DX responses. Then, briefly indicate the desire for a signal report using the proper "Q" signal. For example, "W6BYT de QRP W0RSP QRK?". If no DX has responded to his call, the DX'r has the option of giving you a quick signal report and then continuing his DX'ing, or entering into a QSO. If he has heard some DX response, he will simply wave you away with a "QRX". The proper action is to leave him alone in this case.

(4) Don't "BK". One particular "don't" with respect to calling: don't attempt to break into a QSO already in progress. Newcomers often find it a great temptation after hooking up their rig for the first few times when no "CQ" is found. Two reasons for avoiding this error. First, breaking should be reserved for occasions when an operator has a very specific need to join a QSO. And second, the operators involved in the QSO probably have dropped their r.f. gains back to a comfortable level for copying each other, and have adjusted whatever filter they use for private easy copy. They are not listening for anyone else.

(5) QRP Calling Frequencies. Finally, and this may seem to contradict previous points, the QRP operator should move to the QRP calling frequency every-time he turns the rig on or moves to a different band, monitor the frequency, and then call "CQ QRP". The calling frequencies have been in use for twenty years or so specifically for the purpose of providing a spot where QRP operators congregate and make contacts. Unfortunately, one pivotal axiom that QRP operators follow works against the success of the calling frequencies concept. That axiom is: the QRP operator listens for someone else calling "CQ". This doesn't apply in reference to the calling frequencies. Typically, most of the operators I talk to complain that they never hear anyone on the QRP calling frequencies. I usually ask: "did you call CQ QRP?" and their answer usually is "no". If everyone sits and listens, obviously there won't be any sign of QRP activity. So, the eleventh commandment is: move to the QRP calling frequency and call "CQ QRP". My experience is that two calls will net me a two-way QRP QSO about 50% of the time. Some QRP operator is usually doing some paperwork or constructing some project while the rig is tuned to the QRP calling frequency. When he hears the "CQ QRP" call, naturally he responds. So, monitor the frequencies and call "CQ QRP" on them. The c.w. calling frequencies are: 3560, 7040 (7060 — Europe), 14060, 21060, and 28060 KHz. Easy to remember — 60KHz up from band edge, except 40 on 40. The SSB calling frequencies have never been a success to my knowledge. These: 3985, 7285, 14285, 21385, and 28885 KHz.

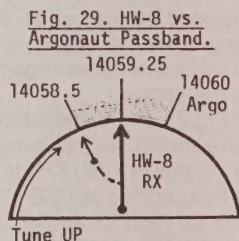
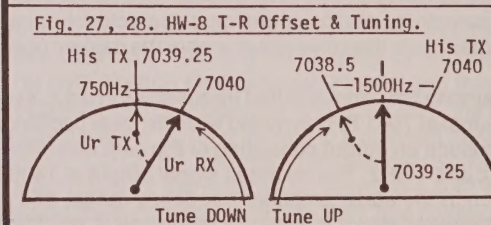
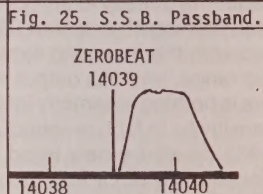
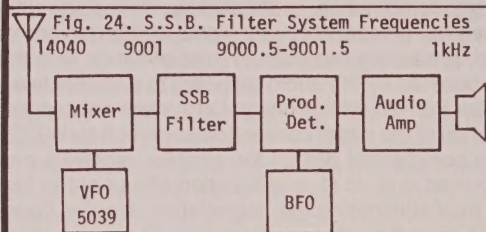
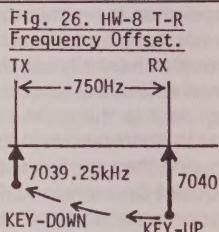
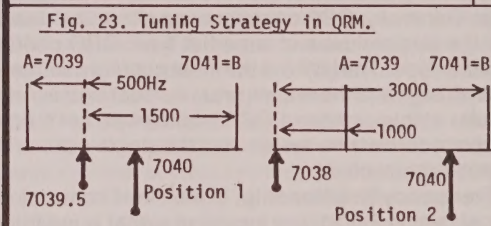
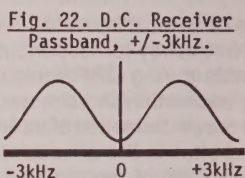
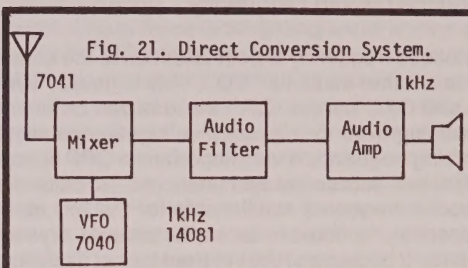
II. Selecting the Calling Frequency

One of the problems that I've noticed frequently is poor attention to the selection of frequency for responding to another station's "CQ". This is usually very noticeable during QRP contests and QSO parties. QRP stations can be heard calling each other in vain, and judging from their respective signals, contacts should result. Selection of transmitting frequency is very important in QRP operation and often is the difference between successful and unsuccessful calls. An understanding of the transmit-receive frequency relationship for the two main types of transceivers in use is essential. As noted in an earlier chapter, crystal-controlled operation is seriously limiting because of the inherent lack of flexibility. V.f.o. operation is an imperative. Generally, QRP operators use either the direct conversion type transceiver or the single-sideband superhet type. QRO operators almost universally use the latter type. The HW-8 is the most popular commercially available direct-conversion design and there are a great number in use. And the Argonaut is the most popular single-sideband QRP transceiver. Let's first examine the differences in the direct conversion system and the single-sideband system, and then explain the problems involved.

(1) Direct Conversion T-R Frequency Relationship. In the direct conversion receiver or transceiver system, shown in Fig.21, the incoming signal is fed from the antenna directly to an r.f.-mixer combination, or simply to a mixer stage without intervening r.f. amplifier. The v.f.o. or local oscillator signal is heterodyned or mixed with the incoming signal, producing two outputs, one of which is in the audio range, and this output is boosted by the audio amplifier to a usable level. There is nothing inherently inferior with the direct conversion system with respect to sensitivity. In fact, re-introduction of the direct conversion approach by W7ZOI in 1968 created a new trend in commercial design for amateur receivers and transceivers when it was discovered that no r.f. amplification ahead of the first mixer was actually necessary, thus eliminating the degradation of noise figure occasioned by such an r.f. stage as well as other deficiencies. The major shortcoming of the d.c. system is in selectivity, and its operational characteristics can have serious negative impact when more than one signal is near the desired operating frequency.

In Fig.21, the relationships among the various signal frequencies in a d.c. system are shown. An incoming signal at 7041 KHz is mixed with the local oscillator (v.f.o.) signal of 7040 KHz to produce an output consisting of the sum and difference frequencies of 14081 KHz and 1 KHz. The summed signal output at 14081 KHz is too high for amplification in the audio amplifier frequency range, and is rejected; however, the 1 KHz difference signal is within its range and is amplified to produce a 1000 Hz audio note. However, note that if an undesired signal is present at 7039 KHz, it also will produce a difference signal of 1 KHz which will be amplified for audio output, and the resulting note will be identical to that produced by the signal at 7041 KHz. Fig.22 shows the output from the mixer in such a case. With the local oscillator at 7040 KHz, and incoming signals at 7039 KHz and 7041 KHz, both are 1000 Hz removed from zerobeat and produce outputs at A and B. No audio filter exists that will distinguish two 1000 Hz signals. Hence, neither signal will be in the clear.

(2) Correct Tuning Procedure. The inability of the d.c. system to distinguish between the incoming signals A and B makes life difficult on a crowded frequency, and some expertise is required of the operator if the receiver is to be useful. There are two basic methods that can be used to "sidestep" the d.c. receiver's lack of selectivity, and the relationships shown in Fig.23 apply. First, the receiver zero frequency can be moved in one direction or another to make signals A and B produce unequal difference signals. If the receiver is tuned down to 7039.5 KHz, signal A will appear as a 500 Hz tone and signal B as a 1500 Hz tone



in the audio output. The two would be easily distinguished by the operator. Suppose, however, that the receiver includes a sharp audio filter which passes only a narrow band of audio frequencies, such as 800-1200 KHz. Both 500 Hz and 1500 Hz output will be attenuated with a loss of audio output level. Moving the receiver back closer to 7040 KHz to bring signal A into the filter passband will also bring signal B into it. The other option is to retune the receiver to the low side of signal A at 7038 KHz (Position 2). In position 2, signal B is removed from the local oscillator by 3000 Hz and most audio filters will eliminate it, leaving a 1000 Hz note from signal A in the audio output. However, the move is a failure if another undesired signal is at 7037 KHz! Ultimately, operators using d.c. system learn how to jockey around for a position that will work. As we'll note below, all this moving around can result in the loss of a contact because, without Receiver Incremental Tuning (R.I.T.), the transmit frequency follows the receive frequency. It is important to stay-put or quickly move back to the initial frequency when starting to transmit — the other station's receiver is tuned to that initial frequency, and if he doesn't hear

you come back because you've dropped down a KHz, he'll perhaps assume you're gone. The best technique here is to try to remember the audio frequency that his signal produced before you made the initial call, and then, while he's going through the routine of turning it back to you, quickly readjust the receiver to that initial tone.

(3) Superhet T-R Frequency Relationship. The single-sideband superheterodyne system is quite a bit more complex than the direct conversion, but its related operational characteristics must be considered as well. The basic single-sideband system is shown in Fig.24. An incoming signal at 14040 KHz is heterodyned with a local oscillator signal at 5039 KHz to produce sum and difference outputs of 19079 KHz and 9001 KHz. This "intermediate frequency" output signal from the mixer is fed through a highly selective crystal filter tuned to pass the difference signal resulting from mixing the local oscillator signal with incoming signals on only one side of the zerobeat receiver frequency. The filtered i.f. signal is then amplified in the i.f. amplifier stage, and converted to an audio frequency by a second mixer stage, the product detector. In Fig.24, the filter bandwidth will pass difference signals between 9000.5-9001.5 KHz, and sharply attenuate i.f. signals not in that range. Now, the output from the first mixer stage is identical with that from the d.c. mixer output except with respect to the frequency: the d.c. system mixer output is in the audio range while the single-sideband system output is somewhere in the h.f. or v.h.f. range. So, if an undesired signal is present at 14038 KHz, mixer output will contain difference signals of 9001 KHz and 8999 KHz. Since the filter will only pass signals within its passband of 9000.5-9001.5 KHz, the difference signal of 8999 KHz resulting from the incoming signal at 14038 KHz will be totally rejected by the filter. The only output signal from the filter will be from the desired signal at 14040 KHz. Fig.25 demonstrates the difference between the d.c. and single-sideband systems for analogous situations. In Fig.25, with receiver zerobeat at 14039 KHz, only output from the signal at 14040 KHz will be heard. The unwanted signal at 14038 KHz is eliminated. Obviously, the single-sideband system is superior in a crowded situation — most of the time.

(4) Tuning Strategy. The ability to monitor both sidebands is often valuable in QRP operation. When calling "CQ", for example, the d.c. receiver permits hearing a response both above and below zerobeat. With the single-sideband system, a response in the unwanted sideband will not be heard. Several operating points should be noted. Operators using single-sideband units such as the Argonaut or a QRO transceiver should be aware of the necessity of tuning $\pm 1/2$ KHz from zerobeat when listening for a response either in routine QRP operations or during contests. In regard to the first, two factors make this strategy a must if contacts with other QRP operators are desired. First, there are still quite a few newcomers who have built out-moded crystal-controlled transmitters for simplicity's sake and select their crystal or crystals based upon the QRP Calling Frequencies. They usually are stuck on one frequency and must resort to calling stations regardless of how close to zerobeat they are. A response from a rockbound QRP station will be missed if his crystal frequency places him in the rejected sideband of an Argonaut. The QRP operator using a single-sideband rig should habitually use the R.I.T. offset-tuning to scan for responses to "CQ's". This is especially true during QRP contests. Secondly, many operators do not correctly understand the transmit-receive frequency relationship in their transceivers such as the HW-8, TenTec PM-series, and homebrew units. As a result, they tune onto a "CQ" in the wrong direction, placing their transmit frequency up to 3 KHz away from zerobeat. Hence, the QRP operator must apply the practice of tuning both sidebands after calling "CQ" or during contest operating.

(5) Transmit-Receive Frequency Offset. Now that the relation between an incoming signal's v.f.o. frequency and the receiver v.f.o. frequency is clear, we can consider the next dimension, namely, the relation between receive and trans-

mit frequency in each unit. Generally, when a v.f.o. is loaded by keying subsequent stages of a transmitter, there is a slight change in v.f.o. frequency as shown by the jump line in Fig.26. While it is possible to eliminate this frequency shift even in homebrew units, when the v.f.o. serves as a common oscillator for both receiver and transmitter sections of a transceiver, the shift is actually necessary. For example, if the unit's receive and transmit frequencies are almost the same, tuning to an incoming signal to produce a 1000 Hz audio note will result in a transmit signal that is 1000 Hz away from the incoming signal's frequency. The other operator will be listening for a response on his calling frequency, not 1000 Hz away from it.

In commercial rigs like the HW-8 and Argonaut, transmit offset is designed into the unit so that when the key is pressed down, the v.f.o. automatically jumps a predetermined amount, usually around 750 Hz. As shown in Fig.26, the transmit offset shifts the v.f.o. exactly to zerobeat when the receiver is tuned to an incoming signal to produce a 750 Hz audio note. The other operator hears a response exactly on his transmit frequency. The important factor is whether the transmit offset moves the v.f.o. upward or downward in frequency. Fig.27 shows a dial like the HW-8's, but a small pointer is attached to the receive frequency dial to illustrate the transmit-receive frequency relation and the importance of the direction in which a station is tuned in. The HW-8 exhibits a "receive-high, transmit-low" relationship, as seen in Fig.27. With the main receive dial pointer set at 7040 KHz, the -750 Hz downshift in v.f.o. frequency during transmit places the transmit frequency at 7039.25 KHz, as indicated by the tacked-on dial pointer. Note that in order to respond to a caller on his frequency, the HW-8 operator tunes from a higher frequency downward, or as in Fig.27, tuning down from 7045 KHz onto the signal at 7039.25 KHz until a 750 Hz audio note results. The transmitted response will exactly (or nearly so) on the caller's frequency. It is important to remember, as noted earlier, that this transmit-receive frequency relation is built in, so moving the receiver around to avoid QRM in a QSO also causes the transmitter frequency to move an equal amount.

Fig.28 illustrates results when the HW-8 is tuned onto a signal from a lower frequency. With an incoming signal at 7040 KHz, tuning upward from 7035 KHz will produce a 750 Hz audio note with the receiver dial at 7039.25 KHz. However, when the key is depressed, the v.f.o. shifts 750 Hz downward, placing the transmitted signal at 7038.5, 1500 KHz below the frequency being monitored by the other station for a response. This may seem an insignificant difference, but it isn't when several other signals — possibly much stronger — are in the vicinity at 7040 KHz in our example. With a fairly crowded band, it is almost certain that the other operator will miss the HW-8 operator's response and not even realize a weak QRP signal is calling him 1500 Hz away.

The situation worsens if the operator on the other end is using a single-sideband transceiver as in Fig.29. For example, the Argonaut uses the typical +750 Hz upward shift in transmit frequency on 20, 15, and 10 meters. Further, the s.s.b. filter eliminates not only signals below zerobeat in frequency, but seriously attenuates signals less than 400 Hz above zerobeat. Suppose an Argonaut or other s.s.b. transceiver has called "CQ" on 14060 KHz, and the HW-8 has been improperly tuned onto the "CQ" from below. At 14059.25 KHz, the HW-8 produces the desired 750 Hz audio note, as shown in Fig.29. However, the HW-8's -750Hz transmit offset places its response at 14058.5 KHz, well within the shaded area of dial representing the sideband which the Argonaut's crystal filter eliminates. The Argonaut operator won't even know that the HW-8 exists, even if its signal is strong. Certainly a missed QSO. On 80-40 meters, the Argonaut (and other s.s.b. transceivers) offset is the same as the HW-8's, but the filter eliminates the opposite sideband. So an Argonaut will copy an improperly tuned HW-8 on these bands, provided the signal at 1500 Hz is strong enough.

(6) Some Strategies. The major points with respect to selecting the frequency on which to respond to a call should be obvious. The QRP operator should know the transmit-receive frequency relationship of his unit and tune onto a signal from the proper direction. The direction of offset can be easily discerned by monitoring the output of the v.f.o. or the output of the local oscillator mixer circuit on another receiver or a frequency counter. The frequency of the oscillator is noted for the receive mode, and then noted for transmit mode. The worst way to learn about the offset direction is on-the-air when, after many missed calls, the HW-8 operator hears a response with a really high-pitched tone and wonders why the guy is calling him so far removed in frequency! Next, as noted above, QRP operators using sideband rigs must develop the habit of tuning ± 2 KHz when scanning for a response in case the other guy is either rockbound or mixed up about his unit's transmit-receive frequency relationship. With the basic understanding of where your signal will show up, several frequency selecting strategies have been found helpful in making a contact.

Generally, operators respond zerobeat with the other guy's transmitting frequency. On a clear frequency, this is the standard practice for the QRP operator. But more often than not, several signals will be heard in the same general vicinity, spread out over perhaps 2-3 KHz. The major objective in this type of situation is to put the QRP signal in the clear as much as possible. The other guy's signal is strong (see above about whom to call) and you'll be able to copy him regardless of his tone. But he has to be able to copy your relatively weak signal in the midst of perhaps several moderate-to-strong signals. On 80-40 meters, you can generally hear the same stations that he hears, and it is a relatively easy matter to pick a clear slot even though it is only 250 Hz removed from the nearest signal. That will help the other operator a great deal. On 20-10 meters, propagation is such that often the frequency may seem totally clear to you, but it is a different story on his end. For example, W9XXX responds to W6KKK's "CQ" on a perfectly clear frequency on 14 MHz. Or so he thinks! One hop west of him, W0RSP's blockbusting QRP signal is in QSO with XZ9Y on W6KKK's frequency. You miss the QSO and can't figure out why because you don't hear anyone else on. Give it another try, but the second time, drop or raise your frequency 400 Hz or so. Or again, W6KKK responds with a "QRZ?". That lets you know he's hearing someone, but can't make it out. Either your signal is too weak, or a stronger station right on top of you is wiping you out. Again, move a few hundred Hz in frequency and try again. Another point to be taken from this example: on the high bands, don't assume that you can't contact W6KKK just because you can hear four other guys calling him. Given propagation differences, W6KKK may not be hearing any of them, and you could have a solid contact. The same method of frequency selection can be applied in s.s.b. operation, but with less flexibility. Everyone calling a "CQ'r" will have carefully zeroed him in so as to sound like NBC at the other end — s.s.b. guys are really stuck on that totally unattainable perfect s.s.b. reproduction of their voices. If you want a contact, sometimes you have to sound like a quack! And appear to not know what you're doing. I can't count the times I've been told to move onto frequency, and at times, during NET excursions, criticisms of my operating skills have been voiced. From these experiences, I have learned that nothing catches the attention of an s.s.b.'r like an off-frequency response. During contests, the zerobeat response habit goes out the window. Contesters want points and will be psychologically attuned to listen across the whole passband of their receiver for responses. Show up anywhere and they'll hear you. But we'll save contest hints for a later section.

III. QSO Strategy

(1) The Call. Making calls is based upon one fundamental goal: intelligibility on the QRP operator's part. On c.w., this means cultivating a perfect fist with evenly spaced characters, no mistakes, and constant speed. Theoretically, everyone has a keyer which is supposed to do all this for him. It doesn't. It is amazing how operators can fool a keyer and the operator on the other end. Remember, words have spaces between them. And when you make an error, some pause should occur before you resume sending subsequent words. The other operator usually is straining to copy the weak signal in the first place, so give him some lag-time for recognition and correction of an error. Secondly, unless the other operator gives you a 579 or requests that you speed up, slow c.w. at 10-15 wpm will elicit more responses and result in more solid contacts than showing off at 35 wpm. It is difficult to copy a weak signal at that speed. So, to reiterate: slow speed, cleanly formed characters, even spacing, pauses, and no errors. On s.s.b., the operator's voice is something he can't do much about, but many of us (with deep voices) find it necessary. The tenor definitely is superior to the bass on s.s.b. If you operate s.s.b. and have a deep voice, in a tight situation you may have to resort to a falsetto speaking style. Second, avoid fancy phonetics. Use the standard list as found in handbooks. These have been found to best produce easily-recognized verbal units. Enunciation is of primary importance. Every syllable should be given its full value. Certain contractions such as "can't" can be turned into "can" with the slightest static crash. Often, it is helpful to repeat everything unless the other operator tells you that you're perfectly copiable.

(2) In-QSO Tactics. Once contact is established, the signal report received by the QRP station helps determine tactics in the context of band conditions and frequency occupancy. Generally, tactics can be grouped under three ranges of signal reports as follows.

(A) In the "best case" of a 58-59 report, no special tactics are necessary, for obvious reasons. However, some judgment as to the accuracy of the report is advisable before proceeding. Frequently, inflated reports are given for various reasons — habit, S-meter inaccuracy, courtesy and others. The other operator's timing can be a clue, provided his habit is to begin transmitting instantly after you sign "K" (go ahead). If he jumps right in, you probably are strong at his end. Another trick is to break for some requested information: "Any QRM NW? BK". If he breaks right in, proceed on the assumption that he copies solidly. Under strong signal conditions, c.w. speed, amount of information, and rag-chewing can be conducted as inclinations dictate.

(B) Frequently, QRP stations receive reports in the 56-57 range, and the subjective judgment of the other operator becomes more important as the signal report drops lower. With a 57 report, the QRP operator can proceed as above, adjusting his codespeed to the other operator's speed and monitoring for any band changes that could make the QRP signal less readable. At 56 levels, it is time to slow down to 15-20 wpm or so and begin paying attention to the factors which influence intelligibility as noted earlier. Requests for repeats of information such as QTH or name given in the previous transmission is a sure indication that the other operator is having some difficulty. If things begin turning for the worse, it is advisable to phase-in weak signal tactics.

(C) The 55 report is perhaps the most common received by QRP stations. S3-4 reports are not uncommon for stations using HW-8's and inefficient antenna systems. At the S5 level, drop back to a codespeed of 15 wpm at most. The other operator needs all the help he can get, so the QRP operator must be very conscious of the tactics for intelligibility noted earlier. Intelligibility is also enhanced by patterning so that the other operator realizes that he can expect you to consistently relay information in a certain manner. For example, timing can be an impor-

tant part of this patterning. After receiving a S3-5 signal report, definitely begin the pattern of pausing at least a second before beginning your response after he signs "K". Use the same length of pause everytime: count to 8 or so, and then begin transmitting. He will then know both where and when to expect the appearance of your weak signal. Similarly, adopt a pause pattern within the transmission itself. At S7-8 levels, running segments of the transmission together doesn't impair intelligibility seriously because everything is in the clear. But at the S5 level and below, a segment of a transmission like: "HIBOB. URRST 5795Z (8 "dits")79. XXQTHVERMILLION, SDVERMILLIONX XNAME . . ." can end up sounding just what it looks like. With a fairly strong signal, the operator on the other end need only make an effort at sorting it out. At the S5 level, he has to make an additional effort just to hear this string of letters. Add a couple sloppy mistakes and the error character consisting of 8 "dits" and intelligibility becomes unintelligibility. Instead: "HI BOB QSL QSL. RST 579 579. QTH VERMILLION, SD. VERMILLION, SD. NAME ADE ADE" gives him units defined not merely by spelling but by time as well.

(D) If repeats are requested even after the above approach has been used, really weak signal tactics must be put into play. First, codespeed should be dropped to 10 wpm or less. Next, all conversational trivia must be omitted, abbreviations used, and multiple repetitions employed. When the going is really rough for the other operator, he must be trusted to know the universal pattern RST-QTH-NAME. Your transmissions should be designed to merely fill in the blanks. Your transmissions should be designed to merely fill in the blanks. In this situation, for example, including your city in the first transmission is a source of possible frustration and confusion. Likewise, while common courtesy demands recognition of the other operator by name, in this type of situation, he understands as well as you do that the signal report is the essential bit of information: a QSL presented as proof of contact for some award can have everything else on it — name, QTH, age, rig, etc. — but it is invalid unless a signal report is indicated. My standard practice in the really-weak signal report situation is to trim the first transmission to the bare bones:

"R . . . R . . . 579 . . . 579 . . . R . . . R . . . 579 . . . 579 . . . SD . . . SD . . . SD . . . K."

Repeating the pattern is intended to preserve the location of the desired information. The important point is: no variation in the pattern. If he specifically re-requests an item, such as QTH, send it alone with perhaps 6 repetitions. Recently, a ZS1 kept me repeating my QTH and name for about 15 minutes on 20 meters when he shouldn't have been able to hear me since he gave me a 229 report. The interesting part of the experience had to do with what he asked me to confirm as having sent in the previous transmission — I had sent only two letters "SD" but he asked me to confirm at least 6! He was missing individual "dots" or "dashes" and what he was coming up with on his scratchpad just didn't make sense. We finally got it straight though. Incidentally, this is one of the exciting aspects of QRP operation — often a QRO operator takes up the challenge of copying the weak signal and just doesn't give up until he walks away with a valid contact in his log. He can feel justifiably proud for having copied a 229 signal across many thousand kilometers! After the basic information has been communicated, continue omitting trivia like "the rig here is . . .". The format "QRP3W . . . QRP3W . . ." works surprisingly well. After recognizing "QRP", the first question in the other operator's mind is "how little power?" and he gets the number immediately. To reiterate, in very-weak signal report situations, trim it to the bone, pattern it, space it, and repeat it!

(E) During a QSO, it is important that the QRP operator continually monitor conditions. The initial report is valid for that moment, and many things can happen in 10 minutes that change the readability situation. For example, on 80-40

meters, the frequency will obviously be occupied while the QRO station is making his transmission. However, when the QRP station begins transmitting, other stations scanning the band usually hear a weak signal and assume that he's out of range, so they settle in and call a nice long "CQ" nearly zerobeat. Unless the QRP operator is monitoring the frequency between words or letters, he merrily pounds brass for another 4 minutes, none of which is copied by the other operator. This is one of the reasons that break-in (QSK) capability is a definite "must" for the QRP station. As soon as another QRO station is heard transmitting on or near your frequency, immediately turn it back to your contact, querying him about QRM and whether he'd like you to QSY (change frequency). If he is experiencing difficulty, no time will have been wasted, and you can move into the clear to resume the QSO.

(3) Deteriorating Propagation. Changes in path propagation can also result in a drop from the initial signal report and readability on the other end. Each band has its own peculiarities with respect to ionospheric behavior during various periods of time. Overall, sunrise and sunset periods exhibit the most significant level of short-term variation in conditions. For close-in U.S. QRP work, variations are typically gradual and usually not enough to wipe out a QSO in 15 minutes or so. However, transcontinental QRP work can be subjected to rather significant variations in such a time span, and DX work even more so. The appearance of QSB (fading) on a previously stable incoming signal is the most easily recognized indication that path propagation is shifting. Hence, the other station's signal strength should be monitored during his transmissions. If the QRP rig incorporates an automatic gain control (A.G.C.) as is the case with the Argonaut, any QSB appearing on a moderately strong incoming signal will be leveled by the A.G.C. and go unnoticed. It is therefore advisable to back-off the r.f. gain control to the point where A.G.C. action is defeated. On the Argonaut 515, this level is reached with the r.f. gain control setting between 4-5. S-meter action is lost, but that is irrelevant. Direct conversion units such as the HW-8 have no A.G.C. function, so audio output is always proportional to incoming signal strength.

In a two-way QRP QSO, QSB can have a serious impact even at the S6-S7 level. Fade dips of several dB can drop portions of a transmission into the noise level. Typically, QRP operators hang in there despite QSB and resort to tactics for S4-S5 signal levels noted above — repeats and short transmissions. This is the proper approach to follow to keep the QSO going as long as possible. First, it is excellent practice in copying weak signals. Second, it provides valuable insight into the difficulties faced by QRO operators in QSO with a QRP station. There is no better way to learn what works and doesn't work than by hearing effective and ineffective tactics used by another QRP operator. However, in situations involving a QRO operator on the other end, courtesy suggests querying him as to whether your signal is affected by QSB, and if so, does he wish to continue ("QRU")? His signal may exhibit QSB, but as yet yours may be unaffected.

(4) Ending the QSO. Often operators listen in on a QSO in progress once they've noted that one end is a QRP station with a decent signal. A practice which has netted me many contacts is a combination of endings. Every transmission is ended with ". . . W0RSP . . . QRP . . . K". This type of ending publicizes your low power level, and even though a listening operator is just browsing around with no specific objective of a contact in mind, curiosity about low power is quite prevalent. So, when concluding a contact, I always affix a "QRZ?": ". . . W0RSP . . . QRP . . . QRZ? QRZ?". That frequently is too tempting for an eavesdropper to pass up, and a response from him results. However, don't expect a response from a QRO station exclusively — look for a weak QRP signal responding to the QRZ. If there is one thing that every QRP operator will do, it is wait around to work another QRP operator! I've been operating QRP for longer than I care to remember, and I'd have difficulty counting all the QRP stations that I've

worked over the years, but just let me hear someone sign “QRP” and I’ll try to work him, even if it means waiting until he ends a QSO.

IV. Weak Signal — Poor Propagation?

In the section on Calling Strategy, the general axiom was noted that selection of stations to call should be based upon incoming signal strength, assuming that a strong signal suggests good propagation. However, the opposite is not necessarily true, i.e., that a weak signal indicates poor propagation. A combination of factors can reduce a QRO signal to a moderately weak signal strength at a given location even though the path is optimum between the two stations. The relationship between path geometry and radiation angle is the key to this reality. A brief example will clarify the fallacy in assuming that a weak signal indicates poor propagation.

In Fig.30, the vertical radiation patterns for horizontal antennas at one-half and one wavelength above average ground are shown in terms of relative field strength across the 0-90 degree range of vertical angles. Height above ground determines the relative intensity of the field across the 0-90 degree range because of reinforcement and cancellation of skywave by ground reflection waves in the Fresnel Zone. As a result, the power fed into the antenna is concentrated into one or more lobes, decreasing to a null between those lobes, rather than expanding equally in all directions. The curves of Fig.30 are not “idealized”, but represent the patterns over average ground; the patterns from real antennas are distorted although the general pattern is present. As can be seen in Fig.30b, a horizontal antenna at one wavelength height over average ground concentrates radiated energy into two major lobes centered at 13 degrees and 48 degrees. Fig.30a plots the relative field strength for the same antenna at one-half wavelength above average ground, with a single major lobe centered at 30 degrees.

Next, let us correlate the relative field strengths for the two heights against the reflection coverage produced by an actual ionosphere for a 21 MHz signal. Curve 31a shows this reflection coverage by plotting distance vs radiation angle for ionosphere Model II, which will be discussed in the forthcoming *The QRP’rs Guide*. Given that ionosphere, the 1900-2206km range is reached by radiation angles between 28.5-32.8 degrees. Fig.31b shows the relative field strength produced at B by station A (Station A curve: height 1 wavelength), and vice-versa for station B at A. Note the dramatic difference in relative field strengths resulting from the fact that the range of radiation angles shown falls within antenna A’s null and at antenna B’s maxima. Across the entire 1900-2060km range, field strength from B is at its maximum. However, field strength from A is at its minimum.

Finally, let’s place the curves into a hypothetical situation, with A and B separated by 2000km, and both using dipoles of equal gain and efficiency. The only difference is that B is a QRP station feeding 5 watts to his dipole, and A is using a typical 100 watt solid-state transceiver which delivers 50 watts to his dipole. Initially, then a 10dB power difference exists between the two stations ($10\text{dB} = 10\log P_1/P_2$). With this initial difference in radiated power, the signal strengths resulting at either end can be estimated. In regard to station B, the radiation angle of 30.4 degrees required for the 2000km geometry is right at the maxima of antenna B’s radiation pattern, with 0.0dB pattern vs path geometry loss. However, that radiation angle is nearly at the bottom of the null for station A, with a relative field strength ratio of 0.2/4, or -13dB below full field strength. Beginning with A’s initial 10dB power advantage, then, the QRP station is at -10dB (10dB below A’s radiated power). However, A’s vertical radiation pattern in combination with path geometry results in a field strength of -13dB. In other words, the 50 watt QRO signal is 3dB weaker at the QRP station than the QRP station’s signal is at the QRO station. Obviously, the QRP station will err in interpreting A’s S5 signal as

Fig. 30a. Antenna Vertical Gain Pattern (referenced to isotropic, dBi).

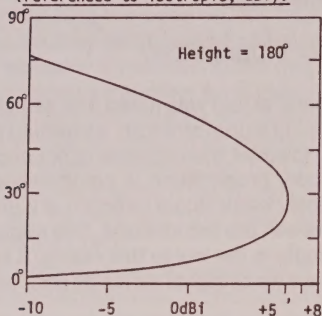
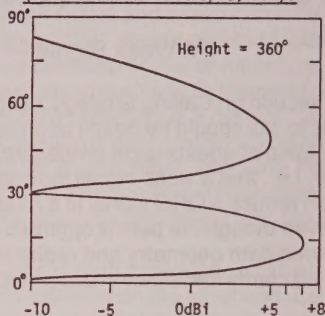


Fig. 30b. Antenna Vertical Gain Pattern (referenced to isotropic, dBi).



indicating poor propagation when, in fact, if A's dipole were at one-half wavelength above ground, his signal would be 2 S-units stronger. Next, let's provide the QRO station with a 3 element tribander instead of the original dipole, providing a 5.7dB additional gain. With the tribander and 50 watts, station A's signal improves a corresponding amount, but that brings his signal up to only within -7.3dB (i.e., $-13\text{dB} + 5.7\text{dB} = -7.3\text{dB}$) of his original dipole's maxima. The QRP station is still at -10dB relative to A's dipole maxima, and the new relation between signal strengths is now in favor of the QRO station, but his signal is only 2.7dB ($-10\text{dB} - -7.3\text{dB} = 2.7\text{dB}$) above the QRP signal. Certainly this is not a sufficient amount to suggest that excellent propagation conditions obtain, although they in fact may exist at the same time.

In short, a weak incoming signal does not necessarily indicate poor path propagation. Frequently, the mismatch of radiation patterns between two stations results in one of them sounding weak at the other location when propagation is actually optimum for the path. Similarly, polarization mismatch has the same effect. QRP operators using vertical antennas should be especially aware of this fact. Given the usual amateur installation, yagis appear prevalently on 40-50 ft. towers, for antenna heights of about $3/4$ wavelength on 20 meters, one-wavelength on 15 meters, and $1-1/4$ wavelength on 10 meters. On 20 meters, then, the vertical user is generally putting out the greatest portion of his power at an angle that is lower than that exhibited by typical yagi installations. On 15 and 10 meters, the difference becomes negligible. However, on 40 and 80 meters, where one-wavelength heights are difficult to achieve, the vertical user will find himself frequently ignored by strong signals which he calls. The point is: he should be calling weak signals because horizontal antennas are almost always radiating at much higher angles than his vertical.

Fig. 31a. 21 MHz Reflection Curve, Ionosphere Model II.

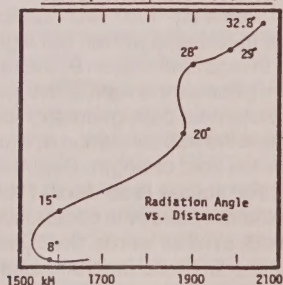
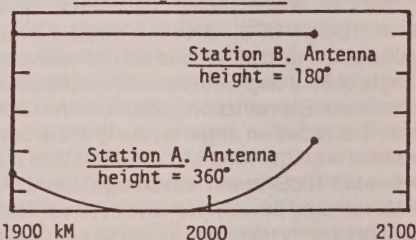


Fig. 31b. Relative Field Strength-Receiving Locations.



Chapter 7

Planning and Operating Techniques: Specific Types of QRP Activities

Much of what has been said in the above sections is applicable to specific types of QRP operations. However, the nature of these specific types of operation often requires additional planning and operating strategies to heighten the chances of successful operation. In this section, approaches to planning and operating in several popular types of QRP operation will be discussed in detail. Overall, many of the points to be made here can be applied across-the-board to a QRP operator's development of a more sophisticated and comprehensive understanding of the numerous factors involved in QRP operation. For example, comments about antennas for Field Day apply equally well to home-station antenna practice and planning. With that in mind, let's look at the annual QRP Field Day.

I. Field Day

The annual end-of-June ARRL Field Day has become a major event in the QRP world and entices many QRP operators out into the field for 24 hours of operating in simulated emergency conditions. The event is a natural for the QRP's because his equipment operates as readily from batteries or solar cells as from the a.c. mains at the home shack. There is something about going into the wilderness (more or less, depending upon location) and carrying along a rig which enables one to remain in contact with civilization. This sounds a bit romantic, but believe me, when you're sitting out there, whether in a state park or on a 12,000 ft. mountain peak, those stories of explorers being marooned in the jungle and lost, except for the portable radio, come to mind. Your rig isn't connected to the outside world except via the antenna, and there really is a dimension of the mysterious associated with the experience. Often as not, just spending a weekend out in the open, away from town and home and mowing the grass, etc., is delightful in itself. Inevitably, operators who get lured into trying a QRP Field Day for the first make always tell the same story — whether they make 10 or 1000 contacts, they had a real ball! Many veterans of club FD's have converted to QRP because it is closer to the whole point of FD — no trailers hauling 10kw generators, gangs to put up 75 ft. towers with stacked arrays, kitchen crews, etc. Just one or two guys, a couple batteries, the rig, and a wire antenna — and making contacts. Eventually, you'll give QRP FD a try too — you won't be able to resist when you read the stories in the annual QRP FD story in **CQ** (May or June issue). One of the first FD phenomena to accept and understand is the prevalence of Murphy's Law: if something can go wrong it will, and if several things can go wrong, the worst thing will. Planning and dry-run testing is essential, as we'll note. Let's look at the planning end of FD first, focusing on site selection, antenna selection, and necessities, before proceeding to a discussion of operating tactics.

(1) Site Selection. Some real effort should go into selecting an appropriate site for the FD event. Two major categories of criteria should be applied: (1) suitability for erecting a good antenna, and (2) advantages offered for a good camping experience.

Antenna Prospects. For the most part, QRP'rs use some type of wire antenna and depend upon available trees for support. If operation is planned on the low bands, a site with trees in the 50-100 ft. range is desirable, while the 25-50 ft. range is adequate for high band operation. These heights provide useful radiation angles for the type of operating involved. While height is a key factor, spacing is

also important. I've headed for some good-looking stands of 100 ft. high trees, excited by the prospect of antenna at 80 ft., only to find that the trees were too close together and no clearance was available between branches for any wire. For wire antennas that require two supports, two trees of the desired height at least far enough apart for the antenna are required. Spacing can be considerably wider than the minimum, since 30 lb. fishing line or bricklayer's cord is cheap and will support a wire antenna regardless of the distance involved. Some wire antennas, such as the inverted Vee, require only one support, and if this type of antenna is to be used, a tree with a long protruding branch at the right height is helpful. A line over the end of the branch will keep the antenna from tangling in the lower branches, and the feed-line can be dropped right to the operating position in the shade of the tree. Other types of support occur in various areas of the country. Fire-towers and old windmill towers are excellent supports if they can be found. If the plan is to take along collapsible masting for the antenna support, avoid dense stands of trees. Old-timers note that an antenna running through heavy tree cover often suffers considerable loss, although the only study that I know of sets this type of loss at about 2dB. My own observation is that there is some truth to this. I put up a beautiful 400 ft. longwire by lacing it through a bunch of trees once — took a lot of sinker-and-line throwing, and once I got it up, I figured I'd be the "big signal on the band." However, I had a miserable time even making contacts! QRP'rs have used a number of methods for supporting an antenna when trees are not available. It is relatively easy to gain 40 ft. of height with temporary installations such as a telescoping T.V. mast, or several 20 ft. sections of 2 x 4 lumber nailed together and guyed appropriately.

Site Advantages. Aside from antenna-supporting trees, site-selection follows criteria ordinarily used in camping, with a few added items. For example, avoid sites contiguous to high-voltage power transmission lines or close to power-distribution installations. One difficulty in operating from commercial campsites like KOA is the possibility that neon signs or appliances associated with the office and facilities will cause undue QRN. In state camps with electrical hook-ups, color TV's will be creating noise across the bands at various points. The best approach is to avoid sites with electrical hook-ups, unless a wilderness section is available with no electricity and is a reasonable distance away from the electrified sections.

Among the advantages to look for are some shade trees and a flat area for the operating table and tent or vehicle. State parks offer a definite advantage in sanitary facilities, as well as swimming and recreational opportunities. The latter should be considered a must if the XYL and kids are to be included in a FD outing. One QRP'r mistakenly figured that the kids would be happy just sitting by the lake catching fish while he racked up contacts — the problem was that once the fish started biting, he had to get in on the action and the score didn't turn out all that well. But who cares! The point is to have fun! State parks also offer the advantage of excellent operating positions — picnic tables. In any case, the operating site should be selected a week or two before FD and checked carefully.

If it turns out to be on private property, a land-owner will usually respond favorably to a request for permission, once the purpose of FD is explained. It is usually enough to note that radio amateurs contribute very important and vital emergency services in times of disasters, and in order to maintain preparedness, the ARRL has been sponsoring the annual FD outing for many years. Landowners that I've approached became more curious and favorable after that, and comments about the battery-powered transceiver and the 24 hour operating period clinched the deal. Expect a visit or two also! At state parks, get clearance for erecting the antenna. I just slung up an antenna in a park in Illinois once during FD, and eventually the ranger came around, puffing on his cigar, and asked: "what the hell is that doing up there." Interrupted a neat run of W6's. I figured I would have some

real problems, except that a really attractive “short-shorts” camper came over and helplessly asked the ranger for assistance. He was off and running. But, having deflected Murphy at that point only worsened the “anything can go wrong” part. Shortly after dark, some kids snooping around with flashlights (always count on snoopy kids!) caught sight of the end of my inverted Vee tied to a 15 ft. tree and located the cord tied at the base of the tree. Naturally, they undid it and proceeded to yank half of the antenna out of the air. My SWR went haywire and out I went, too late! Cancel the rest of the night! In other words, part of the planning strategy is to guess about the type of unnatural disasters that could occur and interrupt FD. Weird things do happen. WA6POC and W6TZA found an ideal site out in a meadow back in 1979 and had it made. That is, until the local cows were turned out to pasture, and being inquisitive creatures, they felt perfectly at home nuzzling around the card-table operating position. That was OK. It was the family of skunks that paraded through after dusk that was the real clincher. Finally, be prepared for the usual weather contingencies — rain, hail, heat, thunderstorms and the like.

(2) Antenna Selection. As with all types of QRP operation, the antenna is the most vital part of the QRP FD set-up, so every effort and expediture must be directed toward getting the most effective antenna for the geographic location where operation will take place. Actually, FD is a favorite of many city-dwellers because it provides the opportunity to try out one of those antennas described in the literature by more fortunate operators who possess antenna farms. It is only for a day, but the FD QRP’r can find out what it is like operating with a 600 ft. longwire tied to his minirig. The actual antenna selected depends upon a combination of factors: location and propagation, directions of highest expected activity, bands used, and available resources.

Location and Gain. A rotatable quad or yagi for 20/15/10 meters would seem the ideal choice at first glance, but not necessarily so in the context of the overall situation. Admittedly, this type of antenna is a bit exotic for a single-man outing, and many QRP’rs prefer going it alone on FD. But with the intense level of activity everywhere in the country, a rotatable antenna can be an unnecessary luxury. An antenna which provides gain in a fixed direction or a bi-directional gain antenna will be just as productive if it radiates toward areas of high activity in the skip zones resulting from its vertical radiation pattern. For example, a wire array in SD with major bi-directional lobes to the east and west provides effective coverage to both coasts where population density, and hence, FD activity is highest. To the east, skip can be as short as 1000km or as long as it desires, and a plethora of stations will be there for the taking. At night, when 80/40 meters are into long skip, the same paths work productively. A different rationale can apply when operation is in a densely populated region of the country, such as VA. Here, a gain antenna aimed to the west on 20/15/10 will permit working stations at 1000km first skip zone (single-hop), and multiple-hop zones including the west coast. But for 80/40 operation, an antenna capable of close-in work via a high radiation angle is desirable, and since the whole eastern half of the country will be within the first skip zone, directivity can be undesirable. Heights then become a strategic factor in selecting an antenna.

Height. Remember that a daytime summer ionosphere exhibits virtual heights of reflection as high as 800km. Recall that, because of the fv-h’ slope and inter-layer cusps, multiple coverage occurs, depending upon the antenna’s vertical radiation pattern. As explained in the previous chapter (“Weak Signal-Poor Propagation?”), an antenna at one wavelength splits radiated power into two major lobes, leaving a null zone as far as reflection coverage is concerned. In contrast, an antenna at a half-wave height concentrates power in a single broad lobe. Depending upon distance to areas of high activity, the lower antenna may be preferable to the higher simply because it will reach that high activity area. So, in

planning FD, an effective strategy is to monitor the bands that will be used on FD during the first half of June. Check skip zones during various times of the day and night to arrive at a sense of the pattern of openings, directions, distances, and times to be expected on FD. If daytime 20 meters is exhibiting short skip throughout the afternoon, and the flux level is bottoming out, very likely short skip will be the daytime rule on FD. Note that if the flux is peaking in the previous weeks, it will decrease during the approach of FD and perhaps bottom out on FD. This means that the F2 ionization levels of the previous weeks that were capable of supporting high-angle radiation for short skip will not be present, and longer skip will result. The effect will be even more noticeable on 15/10 meters. A similar rationale applies to night 80/40 meters, where higher flux levels suggest shorter skip. My experience in the 1975 FD impressed me with the importance of planning for the expected skip. A gain-antenna at about one wavelength on 20 meters had done a fantastic job the previous year, but I had a very difficult and frustrating time with it in 1975. Seems everyone else was using the half-wavelength height, which placed them right in my null zone. I worked some VK's and JA's though, but that wasn't the objective! In short, monitoring the bands and flux can be a prelude to searching for a site with trees of the appropriate height for the expected skip distances.

(3) Antenna Choices. Most newcomers get the impression from the magazine ads that a gain antenna is constructed of aluminum tubing or wire stretched around a spreader structure of the same material. Actually, aluminum tubing is a recent appearance on the gain-antenna scene. They used wire prior to its appearance, and the literature discusses a multitude of wire arrays featuring excellent gain and directivity that are ideal for FD. A wide range of wire antennas are available for use on FD, and we'll note several here: we'll limit this commentary to pros-cons of the various choices. Let me note that verticals are superficially attractive because no supports are needed. However, **there's more to an efficient vertical than meets the eye.** I advise against using a single vertical radiator. First, a vertical has no concentration of radiated energy in the horizontal plane, and power is radiated equally in all directions. While full coverage results, a simple dipole will exhibit some gain in its major horizontal lobes. Second, if short skip is the rule of the day or night, a vertical's low radiation angle makes it relatively useless on FD. Third, planting a vertical is just the start — laying at least 30-40 radials is the rest of the job. Fourth, no one can negotiate his way through a temporary ground screen of 40 radials at 0300 after many hours of intense operating and perhaps a few beers without getting entangled.

(A) Single Wire Horizontal Antennas. Single wire antennas are the stock in trade for most single-man expeditions. Ease of erection and tuning make them attractive. Several options exist in this category: center-fed and end-fed, fed with coax, twin-lead or single wire feeder, require one or two supports.

(1) Dipole/Coax. A single-band dipole fed with 72-or 52-Ohms coax limits operation to a given band. Dipoles for several bands can be attached to a single coax feedline for multiband operation. TV twinlead has been used for the legs of a two-band dipole: the high band legs are formed by cutting one side of the twinlead to resonance and stripping away the remaining wire. The full length of the ribbon lead is used on the low band. While the dipole differs from the inverted Vee only in that its ends are as high as its center, the two are basically the same.

(2) Inverted Vee. The advantage of the inverted Vee design is that it requires only a single center support, which then establishes the antenna's effective height over ground. The radiator ends need not be high off the ground, so low trees, poles and fence posts are adequate for end supports. Or, 200 ft. of nylon cord tied to the ends of the antenna and stretched out to full length and anchored in the ground with a stick provides adequate antenna-end height. A variation of this basic antenna, the long-wire inverted Vee, permits multiband operation with-

out traps. Band-switching is simply a matter of dropping the center of the antenna and connecting or disconnecting shorting clips to include the portions of the total length that resonate on the desired band.

(3) Open-Line Center-Fed. If fed with twin-lead or open-line through a transmatch, a single dipole antenna can be tuned to operate on harmonic frequencies. With a length of about 135 ft., all-band operation 80-10 meters is possible. In addition, balanced feedline such as used for this antenna exhibits considerably lower loss than even the best coax. Bandswitching consists of retuning the transmatch, and it can be used with a single center support, provided the ends can be raised to at least one-half center height.

(4) Longwire. The longwire antenna provides useful gain when four wavelengths or longer. As the number of wavelengths increases, the horizontal lobes move closer to the direction of the wire. While this antenna looks excellent on paper, I'd not recommend it for FD, having worked with samples of 700, 1300, and 2900 ft. When the antenna is really long, it has very limited coverage, but can really pump a signal into that area. Requires two supports and transmatch.

(B) Gain Antennas. As noted earlier, quite a few wire arrays are available for use on FD, and most require the use of tuned feeders (twinlead) and a transmatch. Bi-directional coverage is an advantage for FD, and site selection can include adequate space for a full-size 80 meter array.

(1) Double-Extended Zepp. A single-band antenna providing about 3dB gain in a bi-directional broadside pattern. Leg lengths are cut to 0.64 wavelength instead of the usual 0.25 for a dipole, although the design is the same. The horizontal pattern shows compression of the lobes to about 40 degrees at the -3dB points. Two supports required.

(2) Lazy-H. The Lazy-H requires supports of at least one-half wavelength height, not difficult on the high bands. Broadside horizontal pattern, and depending upon spacing of the elements, can provide up to 6dB gain.

(3) 8JK. My favorite is the 8JK because of its multiband capability. However, the need for element spacers (yagi shape) at the center and ends makes for erection difficulty, although only two supports are needed. Broadside horizontal pattern. Can be mounted like an inverted Vee with one center support, and two 200 ft. end lines to raise ends off the ground.

(4) Vee Beam. The Vee Beam is an excellent choice if three supports are available and correspond to the Vee center angle required for the leg lengths. Provides a bi-directional pattern through the arrow tip of the Vee.

(5) Yagi/Quad. Generally, a tower or collapsible mast must be carried along for yagi or quad installations, unless a windmill tower or some other support is available. Maximum radiation in a single direction can be an advantage if located on either coast. In SD, I consider this a disadvantage. At least two men required for erection.

(4) Preparation. About the only anti-Murphy insurance for FD is adequate preparation for the event. Assume that a weak link exists in the planning, equipment, and antenna, and set out to find it. First off, regardless of the type of antenna selected, put it together and tune it before FD, preferably at the site. Sometimes you can succeed by taking a bunch of wire and a formula, but don't count on it! Simulate FD conditions for checking out the antenna and rig, i.e., battery operation away from the various r.f. grounds that are available at the homeshack. R.f. currents floating around a FD installation can wreak havoc at times. Going out in the field, even if it is just the back yard, for a dry-run will probably reveal all the items that will be needed: antenna tuner, SWR bridge, field-strength meter, current indicators (#49 or #47 bulbs), tape, hook-up wire, alligator clips, spare fuses, extra coax cables for hook-up, pliers, knife, screwdrivers, etc. One item that has to be left at home is the soldering iron. Hence, all solder joints outside the rig should be checked for corrosion, aging and the like, particularly solder joints at coax con-

nectors. FD conditions can impose stresses not normally encountered at the home station in this area, and a trusty piece of coax (the only one brought along) usually fouls at about 0000!

Antenna Erection. Again, dry-run test the procedure selected for erecting the antenna. Don't figure that, since the guy in the article you've read spincast his antenna line over an 80 ft. branch, it'll be a snap for you. Or that the old bow-and-arrow trick will work with an unmodified store-bought arrow. The arrow will be too light to drag even a 2 lb. monofil over a 70 ft. branch and down the other side because of line-drag created by leaves, branches, etc. These methods of erection take some skill. If you have a good throwing arm, you can use my favorite approach. A 6 oz. fishing line sinker at the end of a 6 lb. monofil line will crest an 80 ft. free top and pull the line down the other side handily. However, the line has to be tied really tightly to the skinker, or the sinker will end up in the next county. Always bring a half-dozen sinkers for this approach. Accuracy is helpful. Going through the procedure of putting the antenna up at the site should reveal unexpected hitches. Loading up the antenna at the site likewise will provide an indication of whether it works the same as back home.

Comforts of Life. A day in the field, even under the best weather conditions, requires some attention to regular human comforts. Fatigue builds in direct proportion to discomfort. Operating FD is grueling enough without being exacerbated by a poor operating position. A chair and table (or picnic table) are minimum, unless you have a very comfortable position in your vehicle. Next, don't forget that it gets dark out there and there isn't a light-switch around. A flashlight is inadequate because they're focused either on the rig or the log, leaving a critical blind spot. Good battery-operated camping lanterns provide more light, but some sort of reflector to diffuse the light is helpful — some tinfoil attached correctly will do the job. I take along a couple 12v bulbs with wire leads soldered on and hook them directly to the battery of my vehicle. Lampshades fashioned from tinfoil provide the proper lighting coverage.

In addition, food and liquid refreshments should be planned, especially the liquid. It can get hot and dry out there, and a few hours of s.s.b. operation is enough to wipe out anybody's voice unless drinks are available. Likewise, it gets cold a night, so extra clothing is a must — at least a good jacket and sweater. My second FD revealed that a 100 degree summer day can lead to a 55 degree night! I had to crawl into the sleeping bag every 45 minutes to stay alive, since I only had bermuda shorts, a T-shirt, and a jersey along for clothing! Finally, bug spray is a must unless operation is in the enclosed comfort of an RV or camper.

(5) Operating Strategies. FD operation is hectic and the basic objective is to make as many contacts as possible. Incoming signal levels are usually 2 S-units above those typically encountered across a given band, and there is usually little or no space between signals. A receiver must be able to withstand this r.f. pressure. Direct-conversion receivers sometimes experience front-end overload in such an environment. This problem can be corrected by inserting an appropriate size resistor in the antenna lead, or by installing an r.f. gain potentiometer in the unit. In either case, the lead from the receiver antenna coax jack must be broken for insertion of the resistance. Whether the problem will occur can be estimated by finding a very strong signal, and then tuning away from that signal. If it causes a shift in on-frequency signals when 2 KHz away, the problem will occur on FD. Further, complete break-in capability is essential in helter-skelter FD operation. Commercial rigs such as the Argonaut and HW-8 include this QSK feature. Homebrew units sometimes do.

Zero-Beating Techniques. If a transceiver is used, the technique of rapidly zerobeating an incoming signal is of primary importance. Our discussion in the previous chapter ("Transmit-Receive Frequency Offset") provides details of the process. Responses to FD "CQ's" usually must be close to zerobeat to produce a

contact. So, practice for FD operating should include rapidly zerobeating incoming signals. Develop the habit of tuning across the band so that your transmitting frequency is out in front of the receive frequency — that way your transmitting frequency will automatically be in the right direction. Otherwise, tuning from the wrong direction requires going through zerobeat to the other sideband in order to establish the proper transmit-receive relationship, and there's no time for that during FD.

Band Selection During FD. Once FD begins, the QRP operator is pressed to apply every strategy and skill at his disposal in order to rack up contacts in the midst of fierce competition and bone-crushing signals. The first axiom to apply is the standard one — operate on the highest band that is open at the moment. For starters, this is usually 15/10 meters except at the bottom of the cycle. Two criteria apply as overrides. First, use the highest band that is open with strong one-hop skip. The QRP signal is usually in the second or third layer of signals according to signal strength, and every ionospheric reflection costs. However, ground reflections cause considerably more loss, so avoid working multiple-hop paths if possible. For example, the NY QRP'r may hear 10 meters wide open to CA, OR, AZ, and WA, with very little from the midwest. Two hops are the minimum to span the distance. Ionospheric absorption will be at a minimum on 10 meters, but, the necessary ground reflection can cause 5-15dB loss! On 15 meters, midwestern stations (WO, W9, W5) may be boiling in, and they are accessible via a single-hop. Operate on 15 instead of 10 meters. Even though 10/15 may be open, 20 can be the best band despite higher ionospheric loss if single-hop is prevalent. Generally, a really good antenna is necessary to fight it out on daytime 40/80 meters. If a gain antenna, such as a Vee beam or 8JK at 50 ft. is being used on 40 meters, it may be a very productive daytime band, depending upon location. Respond to the ionosphere!

Band Changing. Resist the urge to switch bands once QSO's come more slowly. There should be a more valid reason for switching, namely, propagation appears to be shifting. Again, one-hop vs. two-hop paths are a prime index. If a string of midwesterners have been worked during the previous hour (from NY) on 15 meters, and then a dry-spell occurs for 20-30 minutes, this could indicate that the midwesterners have moved to another band and hence little activity. But it also could mean a shifting F2 path. This will usually occur in late afternoon as sunset is approaching in NY (or late morning after sunrise). The zenith angle increases from the midwest toward the east, so that the reflection zone ionization will be decreasing and virtual heights going into the readjustment. During early afternoon, however, the dry-spell will not indicate a change in propagation, for the opposite reason. With an Argonaut, instantaneous band-switching is possible, but only the equipment switches that fast. It takes the operator several minutes to read the new band's propagation and get into the pattern that will produce contacts.

Portion of the Band. The QRP signal is on the weak level during FD. Hence, it is best to operate out on the edge of the furious action that usually occupies the bottom 50 kHz of the band (c.w.). This approach is especially crucial if a few watts to a non-gain antenna is being used. Head for the uncrowded portions where stations are spread out and usually operating at lower code speeds. However, if 5 watts to a gain-antenna is being used, don't fear to wade into the thick of the action at the lower end of the band. Here, top-notch operators are battling it out, skimming off the top-level signals in quick succession. This type of operator has no sensitivity to signal strength — he'll hear the S3 as well as the S9 signal. However, be sure that you have the operating skills necessary for the thick of the action — code speeds burn along at 35-50 wpm, and there isn't any time for dilly-dallying.

Operating Style: $E = m^3c^3$. The top-contest QRP'rs follow a sort of Einstein approach — $E = m^3c^3$, translated "Effective operating = move-move-move-

call-call-call" strategy. In routine QRP operations, listening is the key to success, but in a contest, keeping the calls going in rapid sequence is the key to making contacts. Similarly, in routine QRP operation, a sharp filter selectivity is an advantage, but on FD, a wide filter is best because it allows hearing calls a considerable distance away from zero-beat frequency. The operator has to adopt a psychological awareness that will respond to audio tones (on c.w.) very high in frequency compared to the usual 700-1000 KHz tones. He has to monitor for calls and call-signs across that range, and be ready to rapidly zerobeat in the proper direction. Time can't be wasted looking around for the right signal as in routine operation. Skim for strong calls and nail them. Any identifiable call-sign is fair game, even if it has not been ascertained that the given station is calling "CQ FD". Not necessary. It doesn't take much time to zerobeat the station and give a rapid FD-type call, where a lot of quick x2 calls are much more productive than 3x3 calls. Note that it is a waste of time to include the other station's call letters. The idea is to respond instantly to the other operator's "BK" with a simple "DE W0RSP BK" and let it go at that. If you are on his frequency or close to it, he'll either hear you and respond, or be off and running. Timing is important. Lag-time between his "BK" and your "DE" will be read as evidence that you are not calling him. Your "DE" should follow his "BK" with perhaps a single space separating them at most. Tail-ending is an effective strategy. As you are completing a contact, be listening for nearby stations and picking up call-signs. As soon as you are done, be ready to spring on the next station when he's done. Likewise after an exchange ends, always send a "QRZ W0RSP BK". Sharp operators are listening for call-signs to nail, and if they can hear one, they'll respond, and the "QRZ" invites the response. Overall, keep skimming, firing, skimming, firing.

(6) Frustration/Expectations. Strings of QSO's depend upon propagation, your judgments and operating strategy, and luck. My experience, and I note a similar phenomena in many logs, is that QSO's happen in strings. For periods of 20-40 minutes, a few QSO's are logged, and then, all of a sudden, a spurt of one or two per minute for 15 minutes, diminishing to a few in the next 15 minutes. Keep your eye on the hourly average. During the lag times, frustration can occur. However, you just have to keep firing away as fast as possible, mentally analyzing the situation in terms of time vs. propagation. A change in strategy such as calling weak stations instead of strong ones can offset a propagation change for a while. Or moving to the uncrowded portion of the band, or vice-versa. If the frustration becomes unbearable and you are ready to stomp the rig, go for a walk and get mentally reorganized, and then come back firing away. Newcomers to QRP FD lacking contest experience of any kind will find the going quite difficult. This group can benefit immensely by practicing the contesting approach with a sidetone oscillator prior to FD. Speed levels of both copying and sending can be worked up to contest levels with some effort.

Expectations. Remember that the whole point of FD is having fun, and if you have fun just doing it, it won't make much difference whether you rack up 32 or 720 QSO's! First time out, look at it as a learning experience, as indeed it must be. Be willing to sit back and try to figure out what is or isn't working and why. Make notes on what you did to run a string of 15 rapid QSO's. Note whether any single-hop vs. multiple-hop skip phenomena are apparent in your contacts. Check out all the factors we've noted thus far. The point for the newcomer is not to win the FD-Trophy, but to learn how to do it so that next year's performance will show improvement. In quantitative terms, expectations are drastically different for the one-watt output/dipole set-up vs. the 5 watts output/gain antenna set-up.

(A) One Watt/Non-Gain Antenna. Rough going no matter how good propagation is. The dry periods are often long and lacking any contacts. During strings, a 10-12 QSO/hr rate is very good. During band peaks on the high bands, this set-up can reach a 20 QSO/hr rate, but not for long. Expect a rougher time on the low

bands during daytime operation — although I had a run of 29 QSO's in an hour on 40 meters when a "pipeline" opened to the NJ area while I was operating in OH on 40 meters. 8-10 QSO's for night operation is good.

(B) One Watt/Gain Antenna. Provides a marked improvement in results. Dry periods should show some contacts. Peak periods on the high bands run at the 20-24 QSO/hr level, and strings will occur for longer periods of time. Most noticeable is the improvement on 80/40 meters, both day and night operation. For densely populated eastern areas, a 5dB wire array can result in steady day rates of 12/hr. and about the same at night. Depending upon QRN, 80 can be very productive.

(C) Five Watts/Non-Gain Antenna. On 20/15/10 meters, contacts every 3-5 minutes is good. Peak periods can raise to about 20-24 QSO/hr. 40-80 meter day operation is markedly better than at the one watt level. On 40 meters, 10 contacts per hour is good. Again, depending upon QRN and skip, night on the low bands can run at 12-16 QSO/hr for single-hop paths.

(D) Five Watts/Gain Antenna. With a 5dB gain antenna in the clear, high band operation can push you to the limits of your skill and endurance during several hours of peak conditions. Generally, the rate depends upon single-hop path activity. With high activity, 30-40 QSO/hr is not uncommon, and at peaks, racking up 3/minute is not uncommon. Daytime 40 meters can produce fairly consistent contacts at about 12-15 QSO/hr. Night peaks can run to 20/hr. Overall, these figures represent upper limits that appear to be consistent in veteran's logs. Newcomers lacking contest experience must accept much lower limits — as I noted, approach FD as a learning experience. Don't expect to just jump in with the pro's and win. And finally, of course, send your entry into me as part of the QRP FD-Trophy results. A list of scores is published annually (**CQ**, June issue) along with a whole column devoted to comments, reports and photos from participating QRP operators. The **QRP Quarterly** also carries results in the fall issue.

II. QRP Mobile Operation

Running QRP in a mobile set-up shouldn't come as a surprise to anyone — CB'rs have been doing it for years. Since the appearance of the Argonaut in the early 70's, quite a few QRP'rs have routinely operated both c.w. and s.s.b. mobile with excellent success over the years. Perhaps the all-time QRP mobile champ has got to be K4FS, who had logged over 5000 QSO's in over 500,000 operating miles by 1972, collecting over 100 countries, WAC, and WAS at the 5-10 watts input levels. At that point, he turned to trying really low power mobile with 40 milliwatts, and in about 5 months had worked 19 states, 6 countries, and 2 continents. I worked K4FS during a QRP-ARCI party while he was using the 40mw rig on 20 meters, and it's hard to believe, but that low a power gets out despite the limited antenna that is possible. The motivations for QRP mobile operation are varied, but all usually involve the need to be in the vehicle for periods of a half-hour or more. K4FS had a regular daily commuting drive of an hour each way, and started mobiling just to make the drive more enjoyable. In my case, the need for 900 mile roundtrips across the barren wastes of SD led to my first trial of this type of operating. I was so bored I'd have done anything to occupy the time. I figured that I'd at least be able to listen to some interesting QSO's even though I wouldn't have much chance of working anyone, what with 2 watts output to a dinky 7 ft. piece of metal. What a surprise! Often the miles disappeared into a growing list of contacts. For the first several trips, I stuck to c.w. because I figured that it would be more difficult to compete with QRO s.s.b. types on 20 meters. But again, a pleasant surprise. S.s.b. turned out to be more enjoyable since I didn't have to manipulate the keyer with one hand and steer with the other. Some pointers should help introduce non-mobilers to what is involved in getting on the road with QRP.

Mobile Installation. QRP gear is designed to operate from an auto battery power source (13.6v), and the rig is just plugged into the vehicle B + system. However, it isn't quite that simple. Two problems exist that require attention, depending upon the particular vehicle: ignition noise and alternator noise. A noise suppressing kit can be found in any CB store or Radio Shack along with instructions for installation. Two essential circuits are added to the vehicle's electrical system. First, a noise filter is added to the alternator line to suppress noise from that source. Typically, a plastic-encased filter is simply bolted onto the appropriate alternator terminal, and the wire previously hooked to the alternator is connected to the filter output. Takes a few minutes. Second, in fortunate situations, the only other added item is an ignition noise filter to remove that noise from the B + line. The filter is inserted between the B + input jack of the transceiver and the vehicle B + line. The most effective filtering is achieved by mounting and grounding the filter components at the inside of the firewall. Be sure that the chassis metal at the grounding point is emery-clothed or steel-wooled to permit a good ground connection. Then, a piece of coax is used to run the B + to the transceiver. In my case, a 4 ft. piece of RG-174 (1/8" dia. miniature coax) terminated in a phono plug (Argonaut B + input via phono jack) is connected to the output of the noise filter — center conductor to B +, and coax shield braid to the common ground point. Usually this combination will provide suppression of both forms of noise down to the S2-3 level. However, in some older vehicles, deterioration of spark plug wires, alternator ground connection (bolts, brackets, etc.), and distributor connections can cause considerable noise (S8 or more). In difficult cases such as this, the various units should be loosened sufficiently so that a file or piece of emery-cloth can be inserted between the bracket and ground for cleaning purposes. Once shiny surfaces have been obtained, tighten bolts, etc. In the case of leaky spark plug wires, these can be replaced with the shielded plug wire available in all auto stores. Finally, if noise persists at this point, it may be necessary to shield the distributor. Although not a "professional" approach, a method that works is to bunch-wrap about 6 ft. of aluminum foil around the distributor so as to completely enclose it, and then wrap the whole thing with aluminum wire, connecting the free end of the wire to an engine bolt — (clean the contact surface first). Individual vehicles vary widely in the amount of noise suppression that is required. The '66 Tempest that I've driven for several years did not require the alternator filter. If problems are encountered, the **ARRL Handbook** provides further information.

Rig Mounting. Permanent brackets can be fashioned from 1/8 in. aluminum stock if desired. The actual method of mounting the rig depends upon the vehicle structure and preference. I took the "easy-in easy-out" approach instead of permanent brackets. I prefer operating with the front panel of the Argonaut facing upward and flush with the top of the seat-bench. My hand then can rest on the seat while tuning around. The approach is simple. First, a pair of small mailing boxes was located that provided the right leg-length to bring the Argo front-panel up to the level of the seat. These are taped to the rear panel of the Argo with hunks of masking tape. The rig is held in place with a long piece of nylon cord strung around the seat and tied. Takes about 45 seconds to install and remove the rig. Admittedly crude and makeshift, the approach works well, since the Argonaut serves as the fixed-station rig also.

Band Selection. I suppose that it is possible to have a good mobiling experience on 80/75 meters, but the narrow bandwidth of mobile antennas is a definite limitation — with only 14 KHz to move around in, there's not much flexibility. My many attempts on 75 produced a single "QRZ". Bandwidth on 40 meters is slightly better, but my results have been marginal. However, the high bands are where QRP mobile really comes into its own. On the high bands, antenna bandwidth is no longer a limitation. Also, lower propagation loss provides advantages

over the low bands. When 10 meters is open, stateside work with QRP mobile is a breeze, and 15/20 meters are hardly less productive. I really don't find all that much difference among the high bands, except that 20 meter s.s.b. occupancy can be a limiting factor at times. The s.s.b. segments of 15/10 meters always have a lot of open space and QRM from QRO stations is rarely a problem. The earlier discussion of band selection and propagation characteristics applies to mobile as well as fixed operation.

Antenna Selection. Generally, it is advisable to purchase a commercial mobile antenna once decisions about operating bands have been made. Homebrew mobile antennas are described in various articles in the amateur literature, and some savings can be had building your own, but cutting and bending brackets for mounting these things is a pain. A survey of ads in the ham mags will provide a wide selection of antennas. Personally, I prefer the Hustler antenna because of its multiband capability. The initial investment includes a complete antenna for one band, and additional bands can be added by purchasing the top-loading units for those bands. Band-switching requires unscrewing the top-loading section and installing the desired band section. This process requires about one minute. I don't find stopping the vehicle for band-changing a drawback, since I always have to stop periodically to check out this or that new noise or make some adjustment. Finally, the coax connections to the antenna ball-joint or antenna base must be periodically cleaned to remove corrosion build-up; otherwise, considerable loss results. Equipment. Commercial QRP transceivers such as the HW-8 and Argonaut are very good mobile units. In addition, QRO transceivers mentioned in an earlier chapter can be used, but some consideration must be given to power requirements and the like. Many QRP'rs use CB transceivers converted to 10 meters.

73 magazine published a long series of conversion articles that provide details. Such converted CB units are ideal for QRP mobile. About the only accessory that is advisable is an SWR bridge to monitor the condition of the antenna. The Argonaut has a built-in SWR bridge, rendering it "ready-to-go" and if the HW-8 relative output meter is modified to an SWR bridge, it too fits into this category. Depending upon the noise level in a specific vehicle, an auxiliary speaker may be an advantage. In my installation, S7 signals were copiable on the Argo internal speaker, but anything lower than that was difficult. Using headphones is one solution, but with a set of phones on, all noise associated with the operation of the vehicle, including horn blasts, sirens, and other safety sounds, are lost. My solution was an external speaker mounted on the driver-side sun visor, placing the speaker immediately above and to the front of my head. I used a cheapie auto stereo variety speaker by lashing a paint-mixing stick about 12 in. long to it with masking tape, and then securing the speaker by inserting the stick between the visor and the roof. Excellent results, even in my high-noise junker. Operating c.w. in a moving vehicle is a challenge. Some operators mount the keyer on a piece of wood for stability and other methods have been used. I learned to manipulate the keyer paddle with my thumb and middle finger while holding the keyer down on the seat with my index finger. Chuck-holes and bumps always add some variety to the code! But mobile c.w. is quite enjoyable.

Operating Techniques. Mobile QRP operating requires no special techniques, and comments made earlier apply to this mode of operation. Only one additional factor must be taken into consideration. In-motion mobile operation involves a constantly changing environment for the antenna, which in turn affects path geometry. The effects of changing antenna environment are most noticeable in a hilly terrain. Even slight depressions which place the vehicle 40-100 ft. below surrounding terrain cause variations in signal strength. In really hilly country, driving into a valley can result in total loss of the QRP signal at the other station. Going under bridges has the same effect, but it is only momentary. Tunnels are blackout

zones. In short, the QRP mobiler should be continually aware of the possible effects that changing terrain might have on his signal. When going into a depression or valley, notify the other operator about the possible drop in signal strength. When going under bridges or across bridges with a metal superstructure, either turn it back to the other operator, or "hem-n-haw" your way through the obstacle. I've found that QRO operators are even more fascinated with working a mobile QRP station than a fixed QRP station. Often they will hang in there just to see how well the QRP contact holds up. I've been amazed at the number of 45 minute solid contacts I've had both on c.w. and s.s.b., and at the ability to remain in constant contact with a series of stations during a 4-5 hour drive. While I haven't done any DX work except for a few Caribbean stations, many mobile QRP'rs have racked up amazing countries lists on the high bands. Regardless of whether rag-chewing or DX work is your main interest, if you have to drive for more than a half-hour for any reason, hooking up the Argonaut before embarking can make the trip much more enjoyable. You have an occupied passenger seat for company as long as you want to chat with someone.

III. T² QRP WAS

(This section is reproduced from an article by Robert Rose, K6GKU, published in The Milliwatt, VI:3, April, 1975. K6GKU's discussion says it all as far as the approach to working all states with QRP is concerned. In terms of results, Bob came to within 5 states of 5BWAS — a remarkable achievement — before press of duties stopped the project.)

Tenacity Tactics T². Probably one of the first goals of a new QRP'r sets for himself is either DXCC or WAS — most likely the latter. Those fifty pieces of real estate are physically closer than 100 countries and the task, mentally may seem a bit easier. Whether the neophyte ever achieves these goals depends on his ability to apply two factors: Tenacity and Tactics or T². Tenacity implies a lot of patience plus a little something extra. A patient person is "expectant with calmness or without discomfort; also undisturbed by obstacles, delays or failures." A tenacious person will set his sights and hold fast until he succeeds. That is why a tenacious person who has patience will succeed in achieving his goals. The second factor is tactics. The QRP'r has to think out what he is going to do before he embarks on a project, unless he has an inner need to waste time and energy. Tactics include mode of operation, band selection and times, special events, time of operation, and propagation factors. Propagation factors, operating hints, and ways to determine band openings have been discussed in a previous article. In this article, I'd like to discuss band selection for QRP-WAS.

Very seldom does a ham ever sit down and think out which band to attack in a quest for WAS. Usually he looks at his QSL file, finds the band where he has the most confirmations, and off he goes. For a mixed band WAS he really doesn't care what band the "new state" is to be found on. However, mixed band WAS will be achieved more rapidly if he considers the band and its characteristics. When this author contracted QRP fever several years ago, he thought WAS would be a snap on 10 meters alone. After three years of constant digging, it was realized that this was not the case. In fact, the last few tough ones came on 20 and 40 meters. When the prized WAS-QRP certificate came in June 1973, a new objective was chosen — 5BWAS-QRP. The quest for this latter goal over the last 18 months has provided experience and conclusions as to which frequencies provide the best opportunity for accumulating the needed 50 states. Each band represents a different degree of difficulty and requires a different mix between tenacity and tactics. Listed in order of easiest to most difficult, here is how I would rate each band with respect to achieving WAS QRP.

(1) 20 Meters. Strictly a probability function on this band. All the states are there, and you just have to sit and dig them out. Use both c.w. and s.s.b., because

occupancy is very high at both ends of the band. Good 4000km skip prevails in the morning and evening hours, nice short skip for close in states around midday. Tenacity pays off on this band with some time scheduling required, depending upon what states are needed and where they are in respect to your QTH. You will have to contend with QRO nets, cliches, and some bad attitudes, but keep digging. A QRP'r can do it all on this band because occupancy and the time 20 meters is open every day provides the best probability of success.

(2) 40 Meters. This probably comes as a bit of a surprise after all the noise I've made about QRP operation moving up in frequency in order to decrease the absorption factor. However, if I were given the choice between 40 and 15 meters to start on WAS today, I'd choose 40 meters. The reason I give 40 the edge is because of the long-short skip options available on a day-to-day basis. Occupancy is reasonably high on this band and c.w./s.s.b. works equally well. Night is best for longer range contacts, and daytime will provide the states closer in. Although the occupancy isn't as high as 20 meters, probability is on your side: given time enough, you'll find all 50 states.

(3) 15 Meters. I would rate 15 meters very close to 40. However, there are two factors that place a high value on tactics: 1) band openings on a day-to-day basis; and 2) difficult short skip openings. When open, 15 is well occupied on both s.s.b. and c.w. For an East or West Coast station, it will be very easy to get 40-42 states confirmed quickly. However, the close-in states 800-1200km away will be just plain rough and you will have to wait for short skip during Sporadic-E (**Es**) openings. QRO operators handle this problem using high power and scatter propagation — options not open to the QRP operator. You will have to learn seasonal and daily characteristics of **Es**, when to expect openings, and how to use them. This author sat at 42 states confirmed on both 15 and 10 for six months until an **Es** opening in June, 1975, provided AS, UT, NEV, IDA, ORE, OA and MT contacts on both bands in two days! The openings were about two hours long on successive days, and that was it. I had prepared for such an occurrence and knew what I was going to do with respect to bands, timing, QSO length, etc. In this case, tenacity made me sit and listen for the short skip opening, and tactics allowed me to do what I had to do in the time allowed.

(4) 10 Meters. By far, this author has more time and experience on 10 meters over the last 20 years than the other four bands put together. For QRP operation, 10 can be one of the most productive and rewarding bands, and also one of the most frustrating. At solar maximum, it is unparalleled. However, right now, 10 meters must be rated in fourth position for several reasons. When and if it is open, the length of the opening is limited. Propagation is selective at any given time, although 10/9 reports are not uncommon for 2.5 watts output. During this period of the solar cycle, 10 meters suffers an occupancy problem. Last, short skip states are plenty rough and you just have to await those openings as described for 15 meters. For stations on the East or West Coast, the new state count of 40 can easily and rapidly be achieved. However, those last 10 will be slow and hard to come by, especially since Alaska was added to the states. During solar minimum, propagation to these high latitudes is almost non-existent on this band. The word "almost" is used because the word is around that several Alaskan KL7's are alive and well on 10 meters. However, you couldn't prove it at this station, which has been hunting KL7 for two years.

(5) 75-80 Meters. The only reason that this band is fooled with is because it is required for 5BWAS. In an article in The Milliwatt, W0JF commented that occupancy had a lot to do with the ability to make contacts in this part of the spectrum — more so than the level of solar activity. The experiences at this station over the last several months are consistent with his comments. Aside from finding someone to talk to, QRP operation is confronted with high absorption. The quest for new states is pretty well restricted to late winter nights. The best time

here is 0100-0400 local time. Lately the band has been open, and the two watt signal was making it to the East Coast, but there has been virtually no one to work it.

Aside from the proper choice of bands, there are other little tactics to add to your bag of tricks: (A) Use the Novice bands — occupancy is usually quite high. (B) Keep a current callbook and learn how to look up a call in the shortest possible time — 20-30 seconds — so as to pick out the “needed” one quickly. (C) Utilize those state QSO parties. A recent Delaware QSO party filled in this much needed state on several bands at this QTH. (D) Utilize contests such as Field Day, Sweepstakes, and the Open CD Party.

For the new QRP operator, it must be emphasized that the above comments are based upon the experience at this QTH with strictly average equipment. The antennas are a TA33Jr, a Hustler 4BTV vertical on 40 meters, and a pair of Hustler 4BTV's in a phased array on 80 meters. Gear includes an Argonaut and HW-7. Nothing really special here. Any QRP operator can achieve WAS, especially if he applies T². Also, 5BWAS is possible, although this will be a much longer term project and significantly rewarding. It is particularly important to plan the final objective of 5BWAS as the result of an accumulation of milestones along the way. In this manner, your ego gets a boost each time a milestone is achieved, and the interest factor remains high toward the overall goal. For example, let's assume your goal is 5BWAS. A logical set of milestones could be:

1. 25 states — mixed band.
2. 40 states — mixed band.
3. WAS-QRP.
4. 20 Meter WAS-QRP.
5. 40 Meter WAS-QRP.
6. 15 Meter WAS-QRP.
7. 25 States 5BWAS.
8. 10 Meter WAS-QRP.
9. 80 Meter WAS-QRP.
10. 5BWAS-QRP.

Every time you can check off an item on the list, you will get that added little ego boost needed to keep going toward #10. The list looks mighty long when you are at #1, but experience has shown that the achievement of each step will erase a little more skepticism about the feasibility of achieving 5BWAS. By the time you get to #5 and #6, you will be hooked, and the achievement of #10 is just a matter of time. How much time is not known because no one has claimed 5BWAS-QRP yet. But just a couple years ago no one had achieved DXCC-QRP either, and now many stations have gone over the top. Perhaps this article will motivate others who had doubts about their PM3A, HW-8, or Argonaut, to start a check-list and apply T² concepts.

IV. QRP on 160 Meters

Quite frequently, newcomers are unaware of the existence of the 160 meter band (1.8 MHz) since few commercial transceivers operate in this low part of the h.f. spectrum. This is unfortunate in view of the excellent possibilities that 160 offers for close-in, night QRP work from September to May during all portions of the sunspot cycle. The major limiting factor as far as QRP usefulness is concerned is the antenna height required for efficient operation at this low frequency, assuming that a horizontal antenna is the only available option. Several factors make 160 attractive for QRP work.

Allocations and Power Limits. The 160 meter band covers the 1.8-2 MHz portion of the spectrum and is sub-divided into 25 KHz segments, with the maxi-

mum permissible output power levels varying according to geographic location. Along with 30 meters, 160 is the only "low power" band, although power limits are always higher than the 5 watt QRP level. A detailed chart of 160 power limitations can be found in the **ARRL Handbook**. The great power disadvantage experienced by QRP on the 1000 watt bands, hence, is decreased on 160 meters go a maximum of about 13dB, assuming 50% efficiency in the QRO rigs used. This in itself increases the QRP station's odds. However, at this moment, an FCC Proposed Rule Making (PR Docket No. 84-874) threatens reallocation of 160 meters; by the time this book is in print, this threat will have been resolved and the ham mags can be checked for latest news.

Band Occupancy. A second advantage arises from the sparse activity on 160 meters. Except during the two annual 160 meter contests (**CQ** and **ARRL**), there is little, if any, crowding of the band even though it is rather narrow. This raises the chances of a weak signal being noticed and copied. Further, many operators on 160 use QRO homebrew transmitters that operate at only 2-3 times the 5-watt QRP level. And, due to the narrowness of the band, with most activity occurring below 1825 KHz, the QRP station will be prominent as QRO operators look around for someone to contact. In short, the nature of the regulations and the practices of those who use the band render 160 meters quite favorable to QRP operation. In addition, most 160 meter veterans are quite experienced at pulling weak signals out of the noise, which is sometimes rather high. Operating is at a slower pace than on other hambands, and rag-chewing is perhaps the main motivation for operating on 160.

Equipment. Neither the Argonaut nor the HW-8 operate on 160 meters, so an individual wishing to try QRP on this band must either purchase an older transmitter or build his own. Various selections were covered in Chapter 4, and include most transmitters produced during the 1960's. The Viking Ranger (65 watts) or Navigator (40 watts, but rare and costly) are two ideal choices. With respect to homebrewing a 160 meter transmitter, I'd advise against the solid-state route for the newcomer. Transistor gain increases with decreasing frequency of operation, and most modern r.f. power transmitters exhibit such high gain at 1.8 MHz that instability is difficult to avoid, especially in a first homebrew project. The preferable option is to locate an old **ARRL Handbook** with a circuit of a tube transmitter and use that as a construction project. Similarly, circuits will be shown for receiving converters that will permit using the 80-10 meter station receiver or transceiver for 160 meter reception. Incidentally, because of the noise level (galactic, terrestrial) on 160 meters, receiver sensitivities below about 15uv are unnecessary. Simple direct conversion receivers do well on 160.

Antennas. As noted above the major factor determining whether or not to operate QRP on 160 is the possibility of erecting an efficient antenna. At this frequency, a quarter-wavelength height for a horizontal antenna is about 135 ft.! Below that height, antenna efficiency will decrease until at about 30 ft. field strength will be about 15dB below that attained at the quarter-wavelength height. At bare minimum, an antenna height of 40 ft. is required in areas where ground conductivity is from average (12-15) to excellent (30). Antenna efficiency at low heights (less than quarter-wavelength) decreases in step with ground conductivity. However, there is no reason to avoid 160 meters if this height is possible with a horizontal antenna. One very popular short antenna for 160 is the inverted L with an overall length of 136 ft. One end of the antenna is matched to the coax feedline at ground level, run vertically as high as possible, and the remaining wire stretched horizontally to the end support. For the most part, operators are inclined toward shortened verticals for 160. Various schemes have been employed for putting a good signal on 160 with practical vertical heights. The primary requirement for efficiency in the shortened vertical is an extensive radial, ground screen, or counterpoise system. For the moment, let it be noted that a system of about 40

buried radials (quarter-wavelength) increases field strength about 3dB over a system of 8 radials. Back in the early days, an ungrounded counterpoise system was the rule until 1937, when the buried radial system came into prevalence. The amazing fact is that no later studies were done comparing the relative effectiveness of the two systems until very recently. In "Efficient Ground Systems for Vertical Antennas," **QST** (February, 1983), Doty, Frey and Mills have demonstrated through extensive measurements that an elevated counterpoise system, rectangular configuration, attains the same efficiency as a system of buried radials when the number of counterpoise radials is only one-half the number in the buried radial system! The authors suggest a system for 160 meters consisting of a top-loaded 30 ft. vertical over a 100 x 60 ft. rectangular counterpoise of about 50 wires, and claim very impressive results for the system. For the moment, this recent study clearly indicates that excellent 160 meter operation can be achieved on a city-lot.

With respect to the vertical radiator, a frequently used approach is shunt-feeding an existing 40-50 ft. tower with the yagi/quad serving as a capacitive top-loading system. The best discussion of this approach can be found in Capt. Paul Lee's (K6TS) book, **The Amateur Radio Vertical Handbook** (CQ Publishing, 1974, 1984). The attractiveness of this approach is that a grounded tower can be used as the radiator. I have used this approach with very good results. The installation included a Gem-Quad atop a 50 ft. tower, with a 16 ft. whip atop the quad, and base loaded with a large inductance (5 in. dia., about 45 turns close spaced). A maximum of 16 radials of random length served as the ground screen. Several radials were buried along the sidewalk in front of the lot, while others were jammed into the blacktop along the curb. In another installation, an 8JK for 40 meters at 40 ft. provided top-leading for the open-line feeder which served as the vertical radiator. This system was fed through the conventional L-network right in the shack. The ultimate vertical, of course, is a half-wave wire supported by an 8 ft. balloon. The major drawback here, in addition to buying your own helium tank, is that drunken teenagers apparently love watching an 8 ft. balloon rise into the dawn sky after a night of marauding around. However, I won't kid anyone about my preference. My 1900 ft. longwire up 90 ft. was the ultimate, although my 1300 ft. longwire at 80 ft. needed no apologies.

Propagation — Operation. Details about 160 meter propagation have been given earlier in Chapter 3. The general operating techniques noted earlier also apply to 160 with some modification. Typically, there is no need to pick calling frequencies carefully, although you have to be careful about ending up under some strong signal. Operating is at a slower pace than on the higher bands, and most 160 operators are looking around for a nice chat. S.s.b. works as well as c.w. on the top band. Back in the late 60's, I sat in on many s.s.b./a.m. roundtables covering from FLA to CT to ILL while operating a homebrew double sideband transmitter at about 1-watt output. Q5 copy all around. Of course, I was in Ohio with my 1900 ft. longwire. However, I've always been impressed with the effectiveness of QRP on 160 although I've been forced to use minimal antennas. It is nearly impossible to cross the Rockies from this location, although working the east coast is rough but possible. One final note about 160 operating. By mutual gentlemanly agreement, U.S. stations do not operate in the "DX window" at 1825-1830 KHz to avoid QRM'ing foreign DX calling "CQ U.S." DX stations call in that portion of the band and listen 1800-1805 KHz for responses. So, do not incorrectly assume that this portion of the band is a clear frequency — stay out!

V. The QRP-ARCI QSO Parties

Participating in the bi-annual QRP-ARCI QSO parties is a must for every QRP operator. Structured in the contest format for organized operations, these activi-

ties are named "QSO Parties" to de-emphasize the "shoot for the top" and "winner take all" contest attitudes. Instead, the basic purpose of these operating events is to provide QRP'rs with an opportunity to work many others like themselves. For the contest gunners, top-scores qualify them for competition for the "Triple Crowns of QRP" award program. Beyond that, the QSO Parties are a fertile ground for reaping two-way QRP contacts for enjoyment, or for credit toward several of the club's awards such as QRP-25 (25 two-way QRP QSO's), WAS-QRP, WAC-QRP, and KM/W. For me, the real enjoyment of operating in the QSO Parties comes not from being a top-scorer, but from working a whole bunch of QRP'rs whom I've met through the **QRP Quarterly**, **The Milliwatt**, and Operating Reports in my **CQ** "QRP Column," but never had the chance to QSO. From the practical standpoint of mastering operating techniques, the QSO Parties provide excellent exposure to the kind of difficulties which QRO operators have in working us, and this involves real practice in copying weak signals. As noted earlier, it is relatively easy to learn which operating techniques work and which don't by participating in the QSO Parties.

Rules. The Spring QSO Party is scheduled in April, while the Fall QSO Party occurs in October. Current dates are announced well in advance in **CQ**'s "Contest Calendar." The QRP calling frequencies are the focus of activity (c.w. — 1810, 3560, 7040, 14060, 21060, 28060, 50360 KHz; Novice Bands: 3710, 7110, 21110, 28110 KHz). Note that the Novices are split off from the main action by virtue of license restrictions, so higher class (license) operators should make a point of dropping by the Novice frequencies before switching bands. Quite a few Novices are active in QRP, and they deserve the "Elmer" consideration always shown them by the ham fraternity. Scoring is a combination of total QSO points x total number of states/provinces/countries (a given state may be worked on several different bands and count as a multiplier for each band) x power multiplier (4-5w output X2; 3-4w X4; 2-3w X6; 1-2w X8; under 1w X10). 24 hours of operation during the 36 hour Party period are permitted. Entries consist of a log listing and are sent to the Contest Chairman, Eugene Smith (KA5NLY), PO Box 55010, Little Rock, AK 72204.

Antennas. No special antenna considerations apply except where limited band coverage exists. If the existing antenna system excludes operation on any of the h.f. bands because of space limitations or some other reason, consider erecting a temporary antenna for those bands during the QSO Party. For example, suppose that DX'ing is the major station objective and as a result, antenna capability includes only the high bands. This means missing the action on the low bands. A temporary inverted Vee can be erected for 80/40 meters. If space is a limitation (40 x 50 ft. city lot), improvise — stretch an "invisible" antenna made from #28 wire across adjacent lots, or bend the legs to fit into the existing lot. In the first approach, consider friendly relations with the neighbors first, and if possible, ask permission. Otherwise, wait until 2300 when everyone is in bed, and then sling the thing into place, removing it prior to dawn. Without 80/40 meter capability, night operation may be impossible if 20 meters closes down. Since many QRP'rs use marginal antennas on 80-40 meters, scan very slowly, listening down under the noise for weak responses from such stations.

Operating Techniques. The general techniques discussed earlier apply, except for several adjustments for the nature of the QSO Party. First, of course, the "call the strong signal" route is irrelevant, since everyone is operating QRP. Crank up the receiver r.f. gain and be prepared to dig into the noise for weak stations. (2) Make an especial effort to tune ± 2 KHz for responses. (3) Call "CQ QRP" or "CQ TEST" frequently and repeatedly, but very carefully tune for responses. Nothing is more embarrassing to the QRP cause than some hotshot calling "CQ QRP" at 35wpm, breaking a half-second to listen for responses, and then firing away again. Whom do these hotshots expect to hear in that half-

second — 599 + 40dB QRP'rs? (4) Keep the codespeed down to 10-15 wpm unless a strong signal report is received. (5) Give honest signal reports — that is the only way the other operator can choose his operating techniques. If the other guy is down in the noise 20% of the time, he is RST 339! Report "RST 339"! (6) If you receive a weak signal strength report, follow strategies listed earlier. (7) Even if the calling frequency exhibits a loss of activity, continue to call "CQ QRP" for 5-10 minutes. Everyone probably has moved to another band, and new arrivals on your band will appear eventually looking for some action. (8) Read the propagation signs to determine if the band is closing before deciding to switch bands, unless you need new state multipliers and have gathered what you want on the present band. For example, suppose you've been on 15 meters for an hour, and have worked the long-skip states; a switch to 20 can provide access to closer-in states. Overall, keep scanning for QRP calls, and keep making calls. There is a wide variation in the attitudes of the various QRP stations participating in the QSO Parties. Some are aiming for a high score, and follow the rapid exchange (RST, state or province, or country; QRP Number — members of QRP ARCI, output power — non-members) sequence and then move on for a new QSO. Others follow a more relaxed approach, making each contact a little QSO. Personally, I prefer the latter approach and have had 20-40 minute QSO's with W7ZOI, K8IF and other friends during the QRP Parties. On rare occasions, I've had the thrill of two-way transatlantic QRP QSO's with G4BUE and GM3OXX! Above all, I have fun working other QRP'rs!

Chapter 8

R.F. Power Measurements

"Low-loss" and "efficiency" are major concerns in QRP operation, and both are power related. It is important that the QRP operator familiarize himself with relevant power concepts so that he can assess the performance of his equipment. In this chapter, we will discuss basic theory and practical techniques of measuring r.f. power in the transmitter and antenna feedline.

I. D.C. vs R.F. Measurements and Circuit Performance

Until recently, radio amateurs have evaluated transmitter circuit performance almost entirely in terms of d.c. input power. Unfortunately, d.c. input power measurements reveal little about the most important aspect of circuit performance — efficiency. "Efficiency" is defined as the ratio of d.c. input power to r.f. output, or Pin/Pout. In simple terms, efficiency is a measure of the capability of a tube or transmitter circuit to transform d.c. input power into usable r.f. output power. Furthermore, circuit design absolutely requires that r.f. output power be taken into account. In another context, efficiency is a measure of the amount of d.c. power that a circuit component dissipates as heat in the process of generating r.f. power from d.c. input power. This is also termed the "loss factor".

(1) D.C. Input Power & Performance. In general terms, d.c. input power is useless as an index of circuit performance because it provides information only about the circuit's d.c. power dimension; but, the basic purpose of the circuit is to generate r.f. power. Given the d.c. input power to a circuit, no conclusions about either the r.f. output power capability or efficiency of the circuit are possible. In fact, the relationship between d.c. input and r.f. output is ambiguous and different

in nearly every practical transmitter. There are many reasons for this ambiguity, and a brief discussion should alert the newcomer to the factors that are involved.

(a) Production quality control assures reasonably close performance characteristics for all individual transistors (or tubes) of a given type. However, considerable differences are inevitable. Manufacturers rank devices according to reliability and device performance. Aero-space projects and other such crucial areas receive the highest quality devices, with either that grade or the next down going to military applications, and so on down the line until mere mortal radio amateurs get what is left over. Lowest grade "unmarked" transistors are sold at bargain prices because their performance probably doesn't adequately resemble the specs for any identifiable type — they should have ended up on the scrap heap! "Data sheets" published for specific types reflect the fact that despite quality control efforts, variations occur during production. Hence, device characteristics are given in "data sheets" in ranges from "minimum" through "typical" to "maximum". The manufacturer guarantees no more than that a given type device will exhibit a performance in that range. In some cases, such as the Motorola Semiconductor Data Library, only a minimum specification is given for large-signal r.f. transistors, with no maximum specified. For the 2N5589, a minimum collector efficiency figure is given as 50%, and the common emitter amplifier gain figure at 175 MHz is given as 8.2dB minimum. What the 2N5589 will do in an actual circuit, however, can be quite a different story, especially if the circuit operates at 0.1 of the stated frequency. Similarly, the collector output capacitance (C_o) for the 2N5589 is given as a range between a "typical" rating = 15pF to the "maximum" = 30pF. Plugging a 2N5589 exhibiting C_o = 15pF into a 21 MHz circuit adjusted for one with the maximum C_o will produce quite different results!

(b) In addition, transistors and tubes exhibit "frequency sensitivity". The a.c. gain figure, or "beta", of a transistor decreases as the operating frequency increases. The frequency at which beta drops to unity, that is, where r.f. output power is equal to the r.f. input drive power, is designated "fT". Spec sheets usually include graphs showing the fT of a transistor across a portion of the h.f., v.h.f. or u.h.f. spectrums for stated d.c. operating conditions to illustrate the gain vs frequency performance of the device. What is clear from these is that a given device will produce considerably less r.f. output for the same r.f. drive power at 28 MHz than at 3.5 MHz. In fact, the difference is phenomenal. However, a d.c. input measurement will not show a similarly dramatic difference.

(c) When a tube or transistor amplifier is considered in the context of its operation in a circuit, other factors render d.c. input measurements ambiguous. For example, when r.f. drive power is applied to a final amplifier operating in Class-C, that drive power is not entirely consumed in the process of exciting the final transistor. A percentage of drive power is fed-through the final amplifier and appears as part of the r.f. output from the amplifier. This r.f. power is not sensed by d.c. measurements.

(d) In addition to variations in transistor parameters, passive components can influence efficiency in such a way as to make d.c. input power measurements quite misleading. Consider, for example, how an r.f. choke in the B+ lead to the collector of the final amplifier can have such an effect. Assume that the final transistor draws 200ma at 12v for a d.c. input of 2.4 watts, and that the r.f. choke is a frequently used J.W. Miller 100uh type which is wound with #36 or similar size wire and exhibits a resistance of about 3-Ohms. Given these conditions, Ohms Law indicates that this r.f. choke will produce a voltage drop of about 0.6 volts and dissipate about 120mw d.c. power in the process. As a result of this voltage drop, the portion of the d.c. input power remaining for use by the transistor is 2.28 watts ($2.4w - 0.12w = 2.28w$). This represents 5% of total d.c. input power indicated by the measurement. Ideally, circuit efficiency can be no more than 95%. Then, suppose that the circuit employs a 2.7-Ohms resistor between emitter and

ground, the emitter degeneration approach frequently used to achieve a higher degree of stability in typical QRP transmitter circuits. This resistor will dissipate another 108mw of the d.c. input power measured, bringing the total to 9.5%. Now, if the actual transistor in the circuit exhibits a 39% efficiency figure, or the circuit itself is poorly designed, or is a highly inefficient one such as a single stage crystal oscillator, the overall efficiency (ratio of input to output power) can become quite dismal. Beginning with transistor efficiency of 39%, the loss of power introduced by the r.f. choke and emitter resistor brings stage efficiency down to 30%. Other components which are less than 100% at r.f. frequencies add to the loss. It is easy to see how circuit efficiency can drop to 10-20%. In practical terms, one could operate such a circuit at 2.4 watts d.c. input and assume, as is standard practice, an efficiency of 50%, and the r.f. output could be 400mw! (Recall G4BUE's experience as noted in Chapter 1.) Expectations based upon the assumed 50% efficiency figure would be in line with 1.2 watts r.f. output — not with an r.f. output of about 5dB less!

(2) R.F. Power Measurements & Performance. The point should be clear: d.c. input power measurements alone cannot provide reliable indications of transmitter circuit performance. Circuit performance can be judged only when both d.c. input and r.f. output measurements are used in calculations. Of the two types, r.f. power measurements are the more important, for they ultimately indicate the amount of power that the transmitter and feedline can deliver to the antenna — that is the power that performs the “work” in the communications circuit, namely, radiating and propagating an information bearing signal through the lossy medium of the ionosphere to a distant receiver. Now, the 9.5% loss figure in the above example may not seem all that important, since such small drops in power to the antenna probably are not noticeable at a distant receiver. This is true for the QRO case, in which the received signal is relatively strong. A 200-watt signal can sacrifice 9.5% or even 50% and still produce an easily readable input signal to a distant receiver. However, one aspect of receiver performance makes small losses such as this potentially significant.

(a) Yardley Beers (W0JF) explained the subject in a brief article in **The Milliwatt** some years ago. He wrote: “When weak QRP signals are received, often the signal-to-noise ratio is low. Under these conditions a receiver, whose response is linear according to conventional reasoning (i.e., all input signals amplified equal amounts), can become a non-linear detector, and noise can suppress the signal significantly. A simplified explanation will make this clear. We first observe the signal-plus-noise output from the receiver and look for a difference, and this difference is less than the output which the signal would produce in the absence of noise, which is the sum of noise input to the antenna terminals and noise generated within the receiver. For example, suppose that the noise content produces a detector output of 1 volt, and further, that the signal, in the absence of the noise, would also produce an output of 1 volt. Then, because there is a random phase relationship between signal and noise outputs, the signal + noise output corresponds to the sum of signal and noise powers, not to the sum of their voltages. Consequently, the actual detector output due to the signal + noise is the square root of 2 volts (1.41v) rather than 2 volts (power is a function of the square of the voltage or current). The difference between the signal and the signal + noise output is then only 0.41 volt, which we recognize as a readable signal, and the signal has in effect been ‘suppressed’ in the ratio of 1:0.41, or about 4dB, by the presence of the noise. As the signal is increased, however, the effective signal output increases by (a) the direct increase in signal power, and (b) by a reduction of the suppression ratio. Thus, the receiver is in effect a non-linear device at the threshold level. It can be demonstrated mathematically that near the signal-to-noise threshold, an otherwise linear receiver becomes a square-law detector. Hence,

because receivers operate in a non-linear manner near their thresholds, it is important to eliminate every bit of loss in the transmitting system."

In other words, the combination of receiver performance at low signal-to-noise ratios, and the typical power present in a QRP signal at a distant receiver, make every fraction of a dB potentially important. An extra dB can indeed spell the difference between a successful contact and a "near miss". We are speaking, of course, of a difference in r.f. output power.

(b) But there is a second reason for emphasis upon r.f. power measurements. A decrease of 18% in efficiency may or may not be sufficiently large to cause the effects noted above by W0JF. However, such a decrease can serve as an important clue that the transmitter is malfunctioning in some manner. For example, component aging may have introduced losses previously absent. The case of the Argonaut driver transistors "going soft" noted in Chapter 4 is an example. Similarly, dielectric loss in capacitors increases with age. Perfectly shiny solder joints may cover "cavities" inside resulting from dirty leads/pads which deteriorate with age. Overheating of components during soldering can accelerate normal aging. Phenolic slug-tuned coil forms likewise deteriorate, resulting more significantly in detuning of the circuit, although loss increases. The list could be extended. However, the performance results may not be limited merely to a loss in r.f. output. The detuning that can occur across several stages of a transmitter circuit almost inevitably affects signal purity. Harmonics and mixing products increase because of the detuning, matching conditions change, and so on. But the point should be clear: r.f. measurements are needed to detect the drop in efficiency that is the clue to increased losses in a circuit. D.c. measurements alone will not provide that clue!

II. R.F. Power Concepts

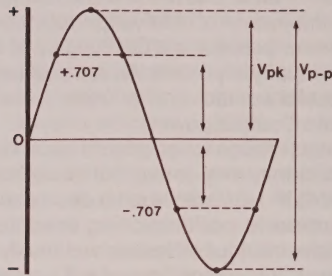
The newcomer is likely to encounter a bewildering array of terms used in regard to r.f. power. Among these would be terms applying to various forms of power as they occur in the communications circuit, such as: "average", "peak", "peak envelop", "incident", "reflected", "radiated", "actual", "real", "reactive", "peak to peak", "r.m.s.", "d.c. equivalent", and "effective" power, to mention several. Before discussing instruments and r.f. measurements, it will be helpful to clarify these various forms of r.f. power. As noted earlier, there are two general categories — d.c. and r.f. (or a.c.). We must begin with d.c. power, since it is the reference for r.f. power quantities.

(1) D.C. Average Power. In basic terms, power is a measurement of the amount of work that a given amount of electrical energy performs per unit time. Electrical power is measured by the unit "watts per second", and its value is based upon the relationship between the two components of electrical energy: (1) voltage, an electrical force which exists between two points due to a difference in electrical charges at those points; and (2) current (measured in amperes), a domino-like flow of masses of freed electrons through a conductor when a voltage is applied to its ends. The relationship among voltage, current, and the resistance of the conductor is defined by Ohms Law, the fundamental law underlying all electrical phenomena. Ohms Law states that a given voltage will produce a given current flow when applied to a load of stated resistance. This is expressed in the familiar formulae:

$$V = IR; R = V/I; I = V/R$$

The quantitative relationship for these three basic components of Ohms Law is defined as unity or one: a force of one volt will cause one ampere to flow through a resistance of one Ohm. Current flow through a resistance expends electrical energy in the form of heat, and the work performed consists of the transformation of electrical energy into thermal energy. Of the various kinds of work performed by

Fig. 32 R.F. Waveform



electrical energy, its dissipation as heat is the most easily measured, and hence serves as the basis for defining the "watt", the unit of power. The watt is referenced to the amount of thermal energy generated by a given amount of electrical energy during a one second time interval. A unity relation exists between the watt and the components of electrical energy: one watt of power is expended when one volt causes a current flow of one ampere, as expressed in the basic power formula: $P = VI$. Note that the resistance, the component upon which the work is being performed, is not included in the power formula — it need not be, for it is implicit because of Ohms Law. When only the resistance and either voltage or current are known, the power formula is rewritten: $P = V^2/R$ and $P = I^2R$, where power is equal to either the voltage squared divided by, or current squared multiplied by, the resistance. In d.c. circuits, no term representing the lapse of time is present — power dissipation remains constant through every subdivision of the one second time unit, and during every subsequent second. Hence, "d.c. power", or "d.c. average power" as it is sometimes termed, represents a constant rate of performing work. It is easily measured by instruments such as a voltmeter and ammeter because both the voltage and current components remain constant while energy is applied. A measurement of voltage and current at one instant indicates what they will be at all other instants.

(2) R.F. "Average" Power. The problem of determining the average power for r.f. electrical energy exists precisely because the values of voltage and current are always changing at a constantly changing rate during any time period in which a measurement could be taken. A glance at Fig.32 will illustrate. If d.c. voltage or current were plotted on the +I/O-axis vs time, the curve would be a straight line parallel with the 0 base-line. However, plotting a sine curve waveform produces quite different values of voltage and current for subsequent instants during the time period. Obviously, measurement of the "average", "actual" or "real" power present in the r.f. waveform for a given one second period is a complex problem. For one thing, instruments other than an oscilloscope cannot follow the changing value of voltage (V) and current (I) components. Fortunately, a mathematical relationship exists between the lapse of time into an r.f. cycle and the magnitude of the voltage and current at that instant in the cycle. The instantaneous value of voltage and current vary according to the sine function of the time elapsed into the cycle, expressed in degrees, or:

$$e = V_{\max} \sin T$$

where e = instantaneous voltage value, T = degrees into the r.f. cycle, and $V_{\max}$ = peak voltage of the wave. Hence, if $V_{\max}$ or $I_{\max}$ for the r.f. wave are known, the instantaneous value of e can be computed for any instant in the cycle by multiplying that known maximum value by the sine of the angle of the instant. For example, if $V_{\max} = 10v$, at 45 degrees into a cycle,

$$e = 10(\sin 45) = 10(.707) = 7.07v.$$

The same is true of the instantaneous current. Since power is a function of either voltage and current, this reveals that the amount of energy available in the wave for dissipation in a load at any instant will be equal to that present for 3 other instants, but unequal to all other instants, except at $T = 90$ and 270 , where V and I are at a maximum, and $T = 0, 180$ and 360 degrees, where the V and I are at zero. To explain the equality at four points, recall that the sine function at 45 and 135 degrees $= .707$, and at 225 and 315 degrees $= -.707$. This sometimes confuses newcomers, since the question arises: how can power be present when the V and I are negative — who ever heard of “negative power”? The explanation is that the “+” and “-” signs simply indicate the direction of current flow through a load and by implication, the polarities at the ends of the load. Using a simple analogy, water flowing west in a pipe still is the same amount of water if for some reason it is made to flow east. Hence, the amount of r.f. power in the 180 - 360 degrees part of the sine curve of Fig.32 is exactly equal to that in the 0 - 180 degrees portion, even though the former appears in the negative region of the axis. “Instantaneous power” is that power available at any instant in the r.f. cycle. Given the above sine formula, all that is required in practice is some method of measuring $V_{\max}$ in order to calculate the various quantities associated with r.f. power.

As noted earlier, since the r.f. signals we deal with exhibit millions and billions of cycle per second, no instrument other than an oscilloscope is capable of indicating instantaneous values. However, those who do not have oscilloscopes are rescued by the function of the simple capacitor as a storage device. Recall from basics that a capacitor charges to the maximum value of voltage placed across it, and retains that charge until a current path for discharge is provided. Hence, a capacitor allows us to record the voltages peaks (implying current peaks by Ohms Law) of a billion cycles per second wave and measure them “at leisure,” assuming that the peaks are of constant magnitude, as is the case with all c.w. waveforms (not so with s.s.b., as we’ll note later). But, notice from Fig.32 that if current from a conductor flows into the capacitor during the positive portion of the cycle, it must flow back out of the capacitor through the conductor during the negative portion. Net capacitor charge then would equal zero! In practice, the capacitor can be fed only the positive (or negative — it doesn’t make any difference) portion of an r.f. cycle through a diode which passes current only in one direction. Combined with a diode, then, a capacitor can be used to record the $V_{\max}$ of an r.f. waveform, which then is measured as a d.c. voltage. This is the technique used in the wattmeter and r.f. probe circuits shown later in this chapter. $V_{\max}$ is also termed the “peak” r.f. voltage, also written “Vpk”. When the total charge between the $V_{\max}$ points of positive and negative portions of the r.f. cycle are being described, it is termed “peak to peak” r.f. voltage, or written “Vp-p” or “Vpk-pk”, and is twice $V_{\max}$. It is more difficult to measure with a simple capacitor and diode circuit, and is generally not used. Given the ability to measure the $V_{\max}$ (implying $I_{\max}$ through Ohms Law) present in an r.f. waveform as a d.c. voltage, an accurate referencing of r.f. power in the wave to d.c. average power is possible both through empirical and mathematical approaches.

(a) Empirical Approach. Since the quantitative basis for d.c. average power (or simply d.c. power) is the amount of heat generated in a resistance per unit time, r.f. power can be referenced to d.c. power by comparison. In an experimental setup, two equal resistances are connected to sources of d.c. and r.f. energy. Once the heat generated by the given d.c. energy (specific current through a given resistance) has been measured, r.f. energy to the second resistance is adjusted until the heat generated is equal to that measured for the d.c. circuit. The $V_{\max}$ (or Vpk) of the r.f. waveform is then measured, and the ratio between v.d.c and $V_{\max}$ is calculated. The resulting ratio has been found to be:

$$V_{\max} = 1.414v.d.c, \text{ or } v.d.c. = .707V_{\max}$$

and the resulting value variously termed the “d.c. equivalent” or “effective” r.f. voltage, written “ V_{eq} ” or “ V_{eff} ” respectively. It is the r.f. wave V_{max} that is necessary to produce the same amount of heat in a given resistance as is produced by a d.c. voltage which is 0.707 the value of V_{max} (the same relation applies to the current component). In real numbers, then, an r.f. wave must have a V_{max} or V_{pk} of 10 volts to produce the same amount of heat as 7.07 volts d.c.

(b) Integration. In the mathematical approach, the instantaneous values of the r.f. voltage (or current) are calculated for a very large number of instants throughout the positive portion of the r.f. cycle. The sine formula noted above makes this possible. Calculations of this sort employ a procedure from calculus known as “integration”, and it is from this procedure that the standard term for heating energy in an r.f. wave is derived, namely, the “root mean square” term which applies to either r.f. voltage or current (but not power). Actually, this term reverses the order of the procedure. The instantaneous values of voltage (or current) are first squared, then the squared values are summed and divided by the time to produce the “average” or “mean” value of the squared values. Finally, the square-root of the mean or average value is taken. Hence, the steps are actually “square-mean-root”, but mathematicians decided to jumble it backwards to “root mean square”. Maybe that was meant as a joke. Some joke! At any rate, the “r.m.s.” value of voltage or current in an r.f. wave is the “d.c. equivalent”, “effective” and “equivalent heating” value for determining the average power in the r.f. wave. The ratio between $V_{r.m.s.}$ and V_{max} (or V_{pk}) is the same as noted above between v.d.c. and V_{max} , where $V_{r.m.s.} = .707v.d.c.$ Calculation of actual or “average” power in an r.f. wave requires use of the $V_{r.m.s.}$ (or $I_{r.m.s.}$) value, since this is the power that does the work. When the V_{max} (or V_{pk}) value is used in the power formula, the result is “peak power” which does not represent the actual work power in the wave, but merely the maximum power present in the r.f. wave at two instants (90 and 270 degrees). One point of confusion frequently occurs because actual work power is calculated upon the basis of r.m.s. values. Even though r.m.s. values are used to calculate actual work power in the r.f. wave, the result is NOT r.m.s. power. R.m.s. power is the (here we go again) root-mean-square of all the instantaneous powers in the wave, and in practical terms, is equal to “average” power multiplied by 1.225. Finally, “peak envelope power” or “p.e.p.” is frequently encountered in the literature in regard to s.s.b. waveforms. This term represents the instantaneous power present in the s.s.b. wave at voice peaks. The average r.f. power in an s.s.b. wave is difficult to calculate since there is no regularity to the infinite variations introduced by pronunciation and articulation by an infinite range of human voices. It can be measured, but not by a simple capacitor and diode circuit. A time sampling circuit is required to measure the instantaneous value of voltage at a large number of instants in the r.f. cycle, followed by a calculator circuit to do the math needed to produce an average power. Manufacturers state that a given unit is capable of X-watts p.e.p., but this figure doesn’t mean much.

(3) Practical Considerations. The QRP operator is primarily interested in a practical application of the above concepts. As noted, practical measurement of r.f. power with simple instruments is limited by one factor: only the maximum or peak value of the r.f. voltage (or current) can be measured in this way. An oscilloscope permits measurement of all values during a cycle, but visual judgments of a sine wave on a CRT cannot be trusted for any great degree of accuracy. Analog meters and digital readouts are capable of greater accuracy. In practice, it is necessary to measure the V_{max} of only half the r.f. cycle, since the second half is a duplicate. Note that we ignore the current component of an r.f. wave in practical measurements — there is no natural method of isolating the r.f. current peak, that is, no diode and capacitor equivalent for current. Hence, formulae for calculating average or effective r.f. power employ voltage and resistance (which is easily mea-

TABLE of Ratios for Converting R.F. Values

(2) By Conversion Factor:	(1) Multiply the r.f. power in these units:				(3) To Get:
	"average"	"r.m.s."	"peak"	"peak-peak"	
	1	0.9	.638	.3185	"average"
	1.11	1	.707	.3535	"r.m.s."
	1.57	1.414	1	2	"peak"
	3.14	2.828	2	1	"peak-peak"

sured), although current is implied by Ohms Law and the basic power formula. Either $V_{r.m.s.}$ or V_{pk} can be used to calculate average effective power in the r.f. wave because of the relation noted earlier. For the r.m.s. voltage value,

$$P = V_{r.m.s.}^2/R; \text{ and}$$

$$P = (.707V_{pk})^2/R \text{ or } P = V_{pk}^2/2R$$

for the peak voltage value. Average, effective power can be calculated from a pk-pk voltage by:

$$P = V_{pk-pk}^2/4R.$$

These alternate formulae are useful because some commercial instruments are calibrated for readout in r.f. peaks volts with the r.f. probe provided as standard equipment; and second, some authors specify measurements for circuits in peak or peak-to-peak values, partly because of an habitual use of the oscilloscope. It is often unclear whether their statements of power values are in the same term, or in average power terms. The accompanying Table provides the ratios for converting from one term to another.

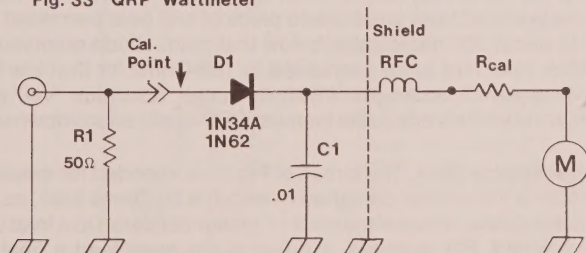
To use the Table, locate the known voltage or current value column (first line); find the unit to which it is to be converted in the "To Get" column; the factor by which the given unit is multiplied to produce the desired unit is read at the intersection of the column and line. For example, convert an r.m.s. voltage (second column) to its pk-pk equivalent (fourth line) by multiplying r.m.s. value by a factor of 2.828.

III. R.F. Measurements Instruments: Wattmeter

There seems to be a general attitude (especially in the G-QRP-C) that the measurement of r.f. power is a difficult task beyond the intelligence and capacity of most radio amateurs. Hopefully, the previous section should correct that attitude. Actually, r.f. power measurements are within the reach of every QRP'r. All that is required is an easily constructed, simple instrument for each of the three types of r.f. measurements that the QRP operator is likely to make. These are described in the remainder of this chapter.

(1) Circuit. The circuit and calibration setup for a simple but accurate r.f. wattmeter is shown in Fig.33. The basic circuit can be used to measure r.f. output power delivered from a transmitter circuit to a resistance of known value. The cir-

Fig. 33 QRP Wattmeter



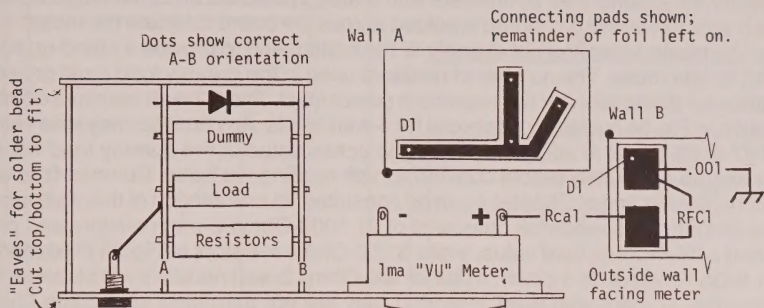
cuit consists of three sections: a dummy load of known resistance, a sensing circuit, and a readout circuit. The circuit is quite simple and its basic principle of operation was noted earlier in this chapter. Diode D1 and capacitor C1 form an r.f. peak voltage (V_{max} , V_{pk}) sensing circuit. When an r.f. signal feeds dummy load R1, D1 permits only the positive half-cycles of the r.f. waveform to flow into C1 and charge it to the peak value of voltage in the r.f. signal. This capacitor voltage (almost a d.c. voltage) is then measured as a d.c. voltage and, together with the value of R1, used to calculate average r.f. power according to the formula given earlier. The upper power limit that the circuit can be used with is determined by the PIV (peak inverse voltage) rating of D1, which ranges from 40-100v for the diodes shown in Fig.33. These types have been used for measurements up to about 30 watts without breakdown. The upper limit can be doubled simply by using two diodes in series, and the voltage rating of C1 must exceed the r.f. voltage expected at that limit. A 100v disc ceramic is adequate. The circuit is simplicity itself, and is philosophically perfect in Aristotle's terms, where the simplest means to accomplish a given task is the most perfect.

Readout of the C1 V_{pk} can be had either with a self-contained meter calibrated in watts, or an external VTVM/DVM. Fig.33 shows a microammeter (or milliammeter) and dropping resistor ("Rcal-ibration") as part of the circuit (note: a voltmeter cannot be used in place of a current-type meter). RFC1 and Rcal are both used with the internal meter. Rcal is selected experimentally to provide full-scale meter deflection for the maximum V_{pk} to be measured. Rcal may be a p.c. trimmer potentiometer. The meter can be re-faced with a self-adhesive address label and a scale drawn for direct calibration in watts. RFC1 and the shield between internal meter and the rest of the circuit are included as a precaution. The purpose of these components is to isolate the meter movement from any currents that may be induced by the stray r.f. field from the dummy load. These can cause inaccurate readings. RFC1 can be any r.f. choke on hand, such as a 1mh or 300uh type, or one could be wound on a suitable Amidon ferrite toroid core (FT-37-61, FT-37-43 etc — see comments in discussion of the **Viking-5**). However, this precaution may not be necessary if power levels are under 3 watts. A G-QRP-C team concluded that the RFC1/shield approach was unnecessary in the four versions of the instrument built and evaluated by the team. Evenso, this problem has been encountered by me and others, so it would be wise to include the RFC1-shield strategy. Alternately, a high-impedance VTVM/DVM may be used to read C1 voltage, and power calculated. In this case, RFC1 and Rcal are eliminated. Accurate readings cannot be obtained with a "cheapie" VOM type instrument, such as those found at Radio Shack. The input impedance of these VOM's is on the order of 1000-Ohms/volt, low enough to distort the load across the C1. Best results will be had with input impedances of 1 meg-Ohms or higher.

The versatility of the instrument may be increased by including switchable dropping resistors at Rcal. The unit can then be calibrated for, say, a 15 watt range, a 5 watt range, and a 500mw range. The minimum sensitivity of the unit depends upon the sensitivity of the meter used. In one version, a high-quality 200ua meter scavenged from an obsolete piece of test gear permitted measurements down to about 200 microwatts; below that point, diode response became non-linear. Also, Rcal had to be decreased to 18k-Ohms for that low level, and meter internal resistance became relatively dominant. A surplus "VU" meter with a 1ma movement is entirely adequate for most QRP applications down to 50mw or so.

(2) Optional Approaches. The circuit of Fig.33 is intended for measurements of r.f. output from a transmitter designed to match a 50-Ohms load, as is usually the case. In some cases, measurement of r.f. power delivered to a load other than 50-Ohms is required. For example, a driver stage must feed a final amplifier whose base input resistance is on the order of 5-15-Ohms. The wattmeter with

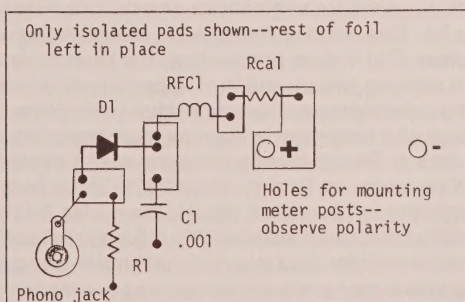
Fig.34. P.C. Stock Wattmeter



internal 50-Ohms dummy load will not be useful in assessing performance of a driver designed to feed such a load. However, the Vpk sensing and readout circuits can be used in connection with a dummy load of any value. Hence, an alternate approach is to substitute a 2-screw terminal strip for the 50-Ohms dummy load, soldering the leads directly across the input connector (coax or phono jack) and wattmeter ground. Then, the correct value dummy load resistor is simply mounted on the terminal strip, a short section of coax (with phono or coax plug on the wattmeter end) is soldered at its loose end right into the output of the driver stage, and Vpk measurements converted to watts using the formula given earlier. Another approach is to construct the sensing circuit as an r.f. probe (see next section), and solder the dummy load resistor into the driver circuit, and take measurements as with an r.f. probe. These approaches permit experimentation with driver (or other) stage component values and adjustments for maximum efficiency.

(3) Construction. Construction and layout are non-critical, provided that the precaution of isolating the meter from the dummy load compartment is taken. A "minibox" or any other enclosure can be used to house the wattmeter. My favorite approach involves fashioning a custom enclosure from double-clad p.c. stock, as shown in Fig.34. The p.c. boards used to mount the dummy load, sensing and readout circuits serve as shield walls. The p.c. boards are laid out to accommodate whatever number of resistors are required in the dummy load. The same strategy is applied to construct dummy loads for other types of units. Basically, the dummy load resistors are "sandwiched" between two p.c. boards which are drilled to mount the resistors, with a bit of space for ventilation between resistors. The sandwich is mounted vertically for the same reason. Fig.35 shows a "jiffy" wattmeter that can be constructed in 20 minutes for mounting directly onto a

Fig.35. "Jiffy" Meter-mounted QRP Wattmeter.



meter with screw terminals. The isolated pads are formed by scratching away copper foil around their perimeters with a sharp penknife tip or file edge. A half-inch wide section of p.c. board is soldered across the board to isolate the meter — it can be made wider and cut at angle at the bottom end to provide a stand-up support for the meter. The number of resistors used in the dummy load must provide adequate dissipation for the maximum power level. The 3 2-watt resistors combination in Fig.34 is entirely adequate for 5-watt levels. Any final dummy load value of 47-to 55-Ohms is adequate, since the actual value of the dummy load will be measured accurately before converting V_{pk} readings to watts. Comments in the attenuator section of Chapter 4 can be consulted. In one version of this wattmeter, the dummy load sandwich consisted of 21 1000-Ohms 2-watt resistors and provided a 51.6-Ohms load value, while 3 150-Ohms resistors in Fig.34 produced a 51.9-Ohms value. In a pinch, a pair of 100-Ohms 2-watt resistors will be perfectly adequate at the 5-watt level, provided they are not permitted to become “hot” (“warm” is OK).

(4) Calibration. The wattmeter circuit is especially attractive because it can be calibrated with a d.c. voltage source, such as a stack of 9v transistor batteries or calibrated power supply, in combination with a VTVM/DVM. The resulting level of accuracy then duplicates the accuracy of the VTVM/DVM used to calibrate the meter. Once calibration is completed, it can be used to calibrate other instruments, such as the Breune in-line wattmeter discussed below. If a lab-grade one-cell d.c. standard is available, accuracy to 3 decimal places is possible — although there is little point to it. If accuracy is the objective, a high-quality Simpson or Weston meter can be salvaged from an obsolete piece of test equipment found at a fleamarket. Some Hewlett-Packard “antique” VTVM’s and other type instruments can be had for \$15 on a good day, and their precision movements combined with 4-inch dial face provide the ultimate! On the other hand, “cheapie” surplus “VU” meters will provide satisfactory accuracy, but the movements are not of the precision variety and usual size of the dial face leaves something to be desired. As noted earlier, a 200ua meter will drop the bottom of the wattmeter’s usable range to about 200 microwatts, below which a correction curve must be plotted. A high-quality meter (Simpson, Weston, Marion Electrical) will provide a linear response curve down to about 100mV, at which point diode non-linearity takes over. With such a meter, deviations of the actual curve from an ideal straight line plot are so minor as to be nearly imperceptible. Similarly, such a meter remains linear to full range. The “VU” surplus type exhibits a “crowding” effect in the top third or quarter of its range, and in a typical example, the 5-watt marker appears at about 80% full-scale, with the upper end of the scale at 13 watts. This is considerably compressed in comparison to a high-quality meter’s upper end which conforms to a square-law response curve. So, when using a cheapie “VU” meter, set the upper limit to a value 25% higher than the intended maximum range, which will then be spread across about 80% of the dial.

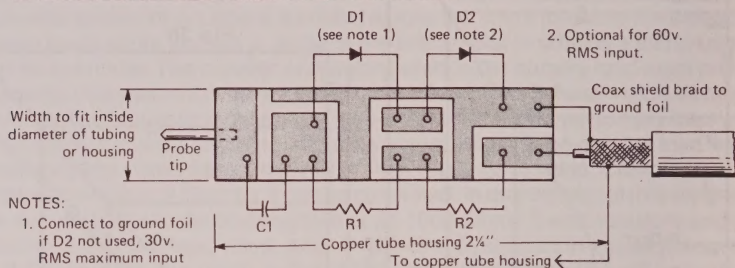
The calibration procedure begins with an accurate measurement of dummy load resistance R_1 . This value is then used to calculate the values of the calibration voltage across C_1 . Before proceeding, the dummy load must be disconnected from the sensing circuit, and the calibration voltage is applied directly to C_1 . R_{cal} must be selected to produce almost full scale deflection at the maximum calibration voltage which represents the maximum power level that the meter is to measure. The size of R_{cal} depends upon the meter sensitivity and maximum V_{pk} . With a 200ua meter, an R_{cal} of about 220k-Ohms permits full scale meter deflection at slightly over 10 watts r.f. input to the meter. A 100k-Ohms R_2 permitted 10 watts at 96% full scale, 5 watts at 80% (13 watts full scale) with a 1ma “VU” meter. Once R_{cal} is selected and inserted, calibration can proceed.

(a) First, if a new meter scale will be inscribed, simply adjust the calibration voltage to a calculated level (10.1v) and draw the appropriate marker (1 watt) on

(b) Second, if the present meter scale is to be used instead of a new scale in watts, a table or graph must be devised to reference the readout scale to watts. For example, if the meter scale is in microamps, the Table would have two columns, one labeled "Microamps" and the other "Watts". The calibration voltage is adjusted to produce the V_{pk} corresponding to the selected power level (i.e., 10.1v for 1 watt), and then the meter reading (such as 64ua) entered on the proper line beside 1 watt (see below).

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Fig.37. R.m.s. Voltage R.F. Probe.



NOTES:

1. Connect to ground foil if D2 not used, 30v. RMS maximum input for 1 diode.

Selection of $R1 + R2$ to form RMS voltage divider in conjunction with VTVM/FETVM/DVM impedance.

R3	R1 + R2
10meg	4.14meg*
11meg	4.57meg*
20meg	8.28meg*

For 10megohm R3:

$$10\text{meg} \times 1.414 = 14.14\text{megohm}$$

$$14.14 - 10 = 4.14\text{megohm for } R1 + R2, \text{ use } 3.3\text{meg} + 820\text{K} = 4.12\text{meg.}$$

$$\text{a.c. peak} = 1.414 \times R3$$

$$\text{RMS} = .707 (R1 + R2 + R3) \text{ A}$$

$$R3 = \text{VTVM/FETVM/DVM input impedance}$$

is necessary above the range of Fig.36. Finally, scale F can be drawn under the meter scale to quickly reference meter readout vs watts.

(d) Alternately, if a VTVM/DVM will be used for readout instead of an internal meter, a calibration chart can be calculated to allow conversion of V_{pk} to average power, using the formula: $V_{pk} = \text{square root of } (P_{\text{average}} \times 2R)$. V_{pk} is calculated for watts in intervals of 1 watt or whatever is suitable, and two columns filled in with matching values:

Power	V_{pk} readout
10w	31.62v
5w	22.36v
1w	10.0v

Once calibration is complete, accurate measurements of r.f. output power are a simple task.

IV. R.M.S. R.F. Voltage Probe

The second device for making r.f. voltage measurements is an r.f. voltage probe which is used along with a VTVM/FETVM/DVM of known input impedance. The r.f. probe is used to measure the r.f. voltage developed across a known resistance of any value, and r.f. power calculated from the r.f. voltage and resistance.

(1) The circuit of the probe is quite simple and consists of an r.f. peak voltage sensing circuit, as seen in Fig.37. C1 serves as a d.c. blocking capacitor which exhibits a low impedance across the h.f. range and permits measurements at points where a d.c. voltage is present. When the probe tip is applied to the r.f. voltage measurement point (with the ground clip attached to circuit ground), C1 permits the r.f. signal to pass while blocking the d.c.voltage. For QRP applications, d.c. voltages rarely exceed 25v, and a standard 100v disc ceramic will do. The r.f. signal passed by C1 is then rectified by D1 which grounds the positive half-cycles. The remaining negative half-cycles are filtered to d.c. by the series divider resistance ($R1$, or $R1 + R2$) in combination with the capacitance of the coax cable lead which connects the probe to the VTVM.

The value of the d.c. voltage presented to the VTVM depends upon the ratio of $R1$ (or $R1 + R2$) to R_{in} , the input impedance of the VTVM. Since the objective is to measure r.f. voltage in r.m.s. units, $R1$ is selected to scale the r.f. peak voltage at the probe tip to an r.m.s. equivalent value ($V_{r.m.s.} = .707V_{pk}$). The input impedance of the VTVM must be known before selecting series dropping resistor $R1$. Generally, most VTVM/FETVM/DVM input impedances are in excess of 1meg-Ohms, but the manual should be checked to verify the actual value. For example, the following instruments exhibit these R_{in} 's: HP-410B VTVM — 122meg-Ohms; Heath IM-17 FETVM — 10meg-Ohms; Sabtronics 2000DMM DVM — 10meg-Ohms; Heath IM-1202 DVM — 1meg-Ohms. The $R1$ value required to scale r.f. peak input to r.m.s. at the meter can be calculated by the formula in Fig.37. Since standard value resistors are unavailable to provide the exact $R1$, the p.c. board includes an extra pad so that the required value can be obtained by connecting two resistors in series. For example, for 4.14meg-Ohms value, 2.7meg-Ohms and 1.5meg-Ohms resistors can be used. The exact value will not result, but high-value resistances with 5% tolerance show a considerable range. Measurements of a group of 2.7meg-Ohms, 5% tolerance resistors showed a variation range of 135k-Ohms: given two handfuls of the right resistors, a combination that is quite close to the desired total value can usually be found. The other option is to "file up" a smaller value resistor, as has been discussed in Chapter 4.

The maximum r.f. peak voltage that can be measured safely is set by the PRV rating of the diode. The germanium small-signal r.f. diodes shown are capable of handling up to about 30v, although they can be pushed to above 40v and still appear to be functional. If damage occurs, the diode will still function, but its response curve will be seriously distorted, leading to serious measurement errors. Should it be necessary to measure values larger than 30 volts r.m.s., two diodes in series will double the maximum limit. An extra pad is provided on the p.c. board for this option. However, the trade off will be an increase in the minimum r.f. voltage that can be measured accurately. While in theory the diode requires at least 0.3v forward bias for conduction, the r.f. probe with one diode is linear in its response down to about 100mV r.m.s., primarily because the change in forward resistance in the diode caused by decreasing bias is virtually swamped out by $R1$. If measurements under 100mV r.m.s. are desired, a correction curve must be plotted on a graph to show actual r.m.s. voltage vs readout voltage.

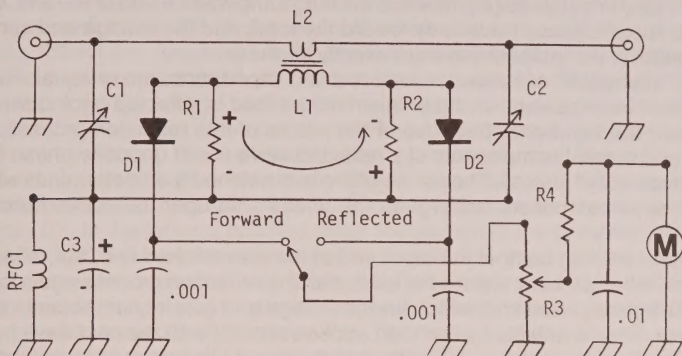
(2) Construction. The important objective is: the probe circuitry must be shielded from r.f. fields developed in the circuit being measured. This is easily accomplished with a trip to the local plumber or hardware store for a section of 1/2-in. copper pipe long enough to house the p.c. board, and a pair of endcaps to fit. The endcaps are then drilled dead-center with holes large enough to permit insertion of the probe tip on the front end, and the coax lead on the other. The probe tip is cut from #12 or #14 solid copper wire, and insulation left on to avoid shorting to the endcap hole. An alligator clip is connected to the probe housing via a 3 in. length of stranded #14 wire, which is bolted to the copper tubing behind the endcap, and serves as the ground lead. The ground clip lead should be kept as short as possible, and connected into the circuit at a point as close to the test point (probe tip) as possible. Otherwise, an inaccurate reading may result. Although a p.c. board is quite small compared to an antenna and we habitually think of the copper connecting foils as "lumped circuits" without linear dimensions, this is not true. A difference of r.f. potential does develop along a 2-inch connecting foil, just as it does along a section of a transmission line or antenna. At the rear endcap, the hole is filed out to fit snugly around the exposed coax braid — a shim can be forced in to insure a good connection. About half of the coax braid is slipped between copper tubing and endcap, which is then jammed on; the other part of the braid is soldered to the p.c. board. An r.f.-tight probe results that is more effective and professional than any I've ever seen in the literature — check out the

primitive housing built from a tube shield in the **ARRL Handbook** for comparison. A 3 ft. section of coax (RG-58, RG-59, RG-174, non-critical) provides adequate distributed capacitance for filtering and is terminated in plugs which match the VTVM input jacks. The p.c. layout of Fig.37 is non-critical, and the extra pads for R2 and D2 can be eliminated to produce a more compact probe if desired, provided the PRV rating of D1 is not exceeded and R1 is close to the required value.

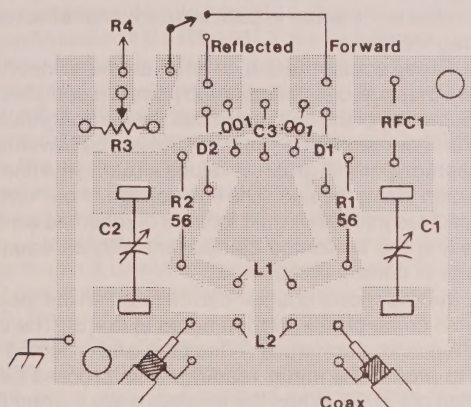
(3) Calibration. Generally, the r.f. probe can be trusted to produce roughly accurate r.m.s. readings if R1 has been selected properly. However, if accuracy is desired, the probe must be calibrated at r.f. using a calibrated wattmeter. The probe cannot be calibrated at d.c. Assuming that the wattmeter discussed earlier has been built and calibrated, calibration of the probe is an easy matter using either the calibrated wattmeter scale or the response curve described earlier (Fig.36). First, the dummy load of the wattmeter is exposed to provide access for the probe tip. Then r.f. power from a QRP rig is applied to the wattmeter and a reading taken with the probe at the dummy load. The resulting r.m.s. voltage readout on the VTVM is then converted to r.f. power in watts and compared to the power indicated on the wattmeter. This can be repeated for several power levels. Probe error will be obvious by dissimilar results. For example, if the wattmeter shows 2 watts while the probe reads 9.8 volts r.m.s., the value of R1 is too large and does not scale by the peak vs r.m.s. ratio of 0.707 in combination with the VTVM input impedance. One can multiply VTVM readout by a correction factor for every reading, or R1 can be retooled to produce more correct r.m.s. readout. The hitch is usually that the input impedance specified in the VTVM/DVM manual is a round figure. Finally, the probe response curve can be determined by plotting a curve modeled on Fig.36, from which horizontal scales A and B are taken directly to begin Fig.38. Vertical scale C plots VTVM readout (representing r.m.s. voltage). In order to locate wattage points on scale D, the actual resistance of the dummy load must be used to calculate watts vs r.m.s. voltage. With this wattmeter's dummy load, 1 watt corresponds to a calculated 7.15 volts r.m.s. Next, horizontals from the calculated r.m.s. on scale D are drawn to intersect with verticals from the corresponding watt-points on scale B. Curve F results from joining the B-D intersection points and is the "ideal" response curve. With the r.f. probe connected to the dummy load, r.f. power is applied at various power levels, and the resulting r.m.s. voltage (scale C) intersection points with scale B verticals marked. The intersection points are joined to produce curve G, which reveals the accuracy of the probe when compared to the ideal response of curve F. Actually, curve G was generated by a probe which had been exposed to around 44 volts r.m.s.: note the non-linear response and the fact that it measures quite low, despite being "right on" when first calibrated. It still produced readings, but they were worthless. The "jiffy probe" discussed below produced the responses indicated by dots: note that it is almost impossible to distinguish ideal curve F from the curve that would result from joining the dots.

(4) K8EEG World Record R.F. Probe. In the attempt to convince amateurs that r.f. power measurement are within the reach of everyone, I decided to prove the point several years ago by establishing a new world record (never was an "old" record) for the least amount of time required for making an r.f. probe. As far as I know, the record still stands: 24 minutes from opening the door until the first actual r.f. voltage measurement! No one has bettered this yet. The trick in establishing the record, of course, was to cut the isolated pads of Fig.37 by drawing a hacksaw blade across the p.c. board rather than etching them. Further, the wired probe was simply wound with several layers of electrical tape, then a good wrapping of kitchen aluminum foil, followed by another wrapping of electrical tape to keep everything in place. Presto! Instant r.m.s.! Very compact, excellent response curve (Fig.38), and I still use it — a veritable triumph of poverty-motivated ingenuity in speculative electronic engineering!

Fig.39. QRP In-line Wattmeter.



PARTS NOTES: C3 - 390pF silver mica; D1-2 - 1N34A, 1N191; RFC1 - 1mH r.f. choke (J.W. Miller 70F103A1, or 15t. #28, Amidon FB-43-801; R3 p.c.b. trimmer pot, 1k-0hms; C1-2 - Elmenco 402 trimmer 1.5-20pF; R1-R2 - 68-0hms; L1 - 50t. #28, Amidon T-50-2 toroid; L2 - 2t hookup wire between ends of L1; M - 1ma meter (see text)



V. Breune In-line Wattmeter/SWR Bridge

The in-line wattmeter provides a method of continuously monitoring r.f. output fed from transmitter into antenna transmission line, or, of measuring r.f. output into a 50-Ohms dummy load during testing and adjustment. The major advantage of the Breune circuit is that it exhibits a flat frequency response across the h.f. spectrum provided certain conditions are met in regard to the toroid inductor and proper adjustment.

(1) Circuit Theory. The wattmeter uses the "directional coupler" circuit shown in Fig.39. This circuit permits separate measurements of either the incident or the reflected waves traveling along a transmission line. Because of transmission line behavior, the actual power delivered from transmitter to line can be determined simply by subtracting reflected power from total incident (forward) power. Second, the SWR (standing wave ratio) can be calculated from measured incident and reflected powers. The directional coupler responds to several aspects of traveling wave behavior on a transmission line, and a summary should be helpful:

(a) All power fed into the transmission line is absorbed in the load (antenna) when the load impedance (Z_L) matches the surge impedance (Z_c) of the line. On a matched line, r.f. waves travel only toward the load, and the voltage and current components of the incident wave are exactly in-phase.

(b) A "mismatch" occurs when load and line impedances are unequal. Part of the incident wave power arriving at mismatched load is reflected back down the line toward the input end. Because of the nature of this reflection process, the voltage and current components of a reflected wave are of opposite phase (i.e., 180 degrees out of phase). The nature of the mismatched load determines which incident wave component undergoes the phase shift upon reflection from the load.

(c) Upon arriving back at the input end of the mismatched line, the reflected wave is re-reflected back toward the load, with the reflection process again causing a 180 degree phase shift which brings voltage and current components back into phase. This re-reflected wave then adds vectorially with the next wave being fed into the line. The incident wave then is the sum of re-reflected wave and the new incident wave appearing at line input. Hence, power fed into the line is incident power less reflected power. The power absorbed in the mismatched load is equal to power fed into the line less that absorbed in line loss.

(d) The ratio of magnitudes of voltage and current components in both the incident and reflected waves is determined by the ratio of line surge impedance to load impedance; that ratio is the same in both incident and reflected waves, and remains constant along the line.

(e) If a voltmeter is placed across the line, or an r.f. ammeter inserted in the line, the voltage and current measured at the insertion point is a complex quantity produced by the vector summing of the instantaneous values (magnitude and phase angle) of the voltage and current components of the waves traveling in opposite directions past the insertion point. A graph of values all along the line results in the familiar SWR distribution along the line. The line voltage or current measured in this manner can be resolved into either their forward or reflected wave instantaneous values by cancelling the unwanted component with an equal magnitude, opposite phase voltage or current component.

In practical terms, the directional coupler can distinguish the incident from the reflected wave because of the phase relation noted in (a)-(b). The coupler develops two sample voltages for each wave — incident and reflected — which are summed vectorially to produce a meter reading. This process becomes clear through an examination of Fig.39. When the incident wave current flows through link L2, a voltage is induced across primary L1, resulting in current flow through the current loop in the direction shown (established by the relative winding directions of L1-2). Two equal sample voltages appear across R1 and R2 with the polarities conventionally marked (" + " for the terminal into which current flows). These are the current-derived sample voltages. Next, C1-2 and C3 form a capacitive voltage divider across the line, so that the voltage component of the incident wave charges C3 with the polarity indicated. C1 and C2 are adjusted so that the voltage sample appearing across C3 equals the current-derived voltage samples appearing across R1 or R2 when the line is terminated in a load equal to its characteristic (or surge) impedance. This is possible because the ratio of voltage and current components is set by the surge impedance of the line. Given a 50-Ohms line, the ratio of wave voltage to current will always be the same, regardless of power level. The basic coupler circuit is completed by diodes which rectify the total voltage developed across either R1-C3 or R2-C3 for readout on the meter. Note the effect of meter measurement point upon readout. In the forward position, the sample voltages at C3-R1 are connected in series, so the meter reads their sum. In the reflected position, however, C3-R2 are "bucking" (" + " to " + ") and the resulting voltage across the negative terminals is zero. If the transmitter is connected to the

output terminal and load to the input side, current flows in L1 in the opposite direction, and the polarities of the current-derived sample voltages across R1 and R2 are reversed. In the reflected position, the meter then reads C3-R2 connected in series. C3-R1 are "bucking" in the forward position and cancel. In other words, for one measurement point, the current-derived sample voltage is of the same polarity as the C3 voltage sample for the incident wave, and of opposite polarity for the reflected wave. When both incident and reflected waves are inducing voltages across R1 and R2, the situation becomes complicated. The actual current-derived sample voltage across each resistor is the vector sum of the incident and reflected wave current components. The same is true for the sample voltage across C3. In the forward position, then, the portion of the complex sample voltages at R1-C3 due to the reflected wave cancel, leaving only the incident wave components for measurement. Note that switching the meter to the reflected position reverses the polarity relations, and the incident components cancel, leaving the reflected components for detection. The meter, in effect, provides an indication of the relative magnitudes of incident and reflected wave components. Since incident or reflected powers are a function of the square of their respective voltage or current components, the meter can be calibrated in watts.

(2) Design Considerations. The frequency range of the instrument is determined by the relation between R1-R2 and L1. The lower frequency limit for useful readout is at a point where the resistance of R1-R2 becomes significant with respect to the reactance of L1 as regards current flow in the loop. The objective is to select of combination of R1-R2 and L1 in which the reactance of L1 is still quite large at the lower frequency limit compared to R1-R2; a ratio of 10:1 satisfies this condition. Otherwise, the voltage induced across L1 by line current is so small that loop current is affected by R1-R2 and and R1-R2 sample voltages are no longer proportional to line current. Theoretically, the current-derived sample voltage remains the same across the useful frequency range of the instrument because rising coil reactance cancels any increase in coil current with rising frequency. At the upper frequency limit, where the series-resonant frequency of L1 is approached, L1 reactance rises toward infinity, and current flow drops below the level which provides a useful sample voltage. It should be noted that removing turns from L1 (decrease its reactance) increases the current-derived sample voltage at R1-R2. The increase is a function of the square of the turns ratio (before and after removal), while the induced voltage decreases simply according to the ratio of the turns. The lower frequency limit of the unit can be extended downward by selecting a toroid upon the basis of its frequency response curve. Amidon Associates, 12033 Otsego St., N. Hollywood, CA 91607, provides sample "Q" curves for their assortment of toroids. These show that the "2-mix" toroid is most useful in a wattmeter designed to cover the h.f. bands. The 2-mix shows maximum "Q" around 3 MHz with a dropoff above that point. Hence, the toroid increases inductive reactance at the low end of the frequency range, while the winding itself largely determines inductive reactance at the high end.

(3) Parts selection and p.c. board layout is intended to achieve bilateral operation of the circuit as closely as possible (i.e., the coupler produces identical readings regardless of which side is fed the input signal). Thus, R1-R2 and D1-D2 should be selected to exhibit matched values to insure balance between the forward and reflected readings. A VTVM/DVM is used to select nearly identical values for R1-R2. Similarly, the forward and reverse resistances of a handful of germanium diode can be measured to produce a matched pair. Germanium diodes are used in the wattmeter because of their lower forward conduction voltage requirement (0.3v vs 0.7v for silicon diodes). This is important in a unit intended to measure QRP power levels. C1-C2 (Fig.39) should exhibit a low minimum capacitance of around 5pF. Miniature ceramic trimmers such as a Johnson #275-0430-005 (5-30pF) or an Elmenco 402 (1.5-20pF) type may be used. One

precaution in designing a p.c. board is to keep the r.f. portion of the circuit on as limited an area of the board as possible. Care must be taken in winding L1-L2. The turns of L1 should be spaced evenly around the toroid circumference, with L2 positioned between the ends of L1. Likewise, coax or phono receptacles should be mounted close together to permit direct and short leads to L2.

A single meter is switched for forward and reflected positions to aid in obtaining bilateral balance. Meter sensitivity is not critical, bearing in mind that a QRP wattmeter must measure quite small voltage samples at the low end of its range. As noted earlier, the sizes of R1-R2 and L1 permit a minor amount of leeway, but a point of diminishing returns is met when pushing R1-R2 and L2 downward to produce a current-derived sample voltage at low power levels. D1-D2 resistance is a limiting factor. A 1ma meter will produce full-scale deflection down to about the 2-watt level. A 200ua meter will allow fairly accurate readout at low levels, but the tradeoff is that the upper limit must be 2 watts or lower. One problem with using a more sensitive meter (i.e., 50ua or 100ua) is that residual currents flow in the coupler circuit even when it is perfectly balanced, and these will affect such a meter, rendering complete nulling of the coupler impossible. Since the circuit senses voltage and current components, any dial scale calibrated in watts will exhibit a logarithmic scale (power is a function of the square of wave components). Usually a separate scale will be necessary for a unit which includes switched meter dropping resistors for a high and low range (i.e., 10 watts, 1 watt) because diode response is non-linear across such a wide range. R4 is selected to permit maximum meter deflection at the desired power level at some setting of R3, the meter adjust potentiometer. Since the unit is used to measure SWR also, full scale readout at lower powers is possible by using a front panel potentiometer at R4. With R4 at maximum resistance, R3 is adjusted to produce full scale reading at the upper limit (5 watts). R4 then can be decreased to obtain full scale readout of lower power levels for SWR measurements. An SWR of 3:1 occurs at about half-scale.

(4) Adjustment. Before use, the sample voltage across C3 must be equalized with the current derived samples across R1-R2 by adjustment of C1-C2. For this "nulling" procedure, the following is required: (a) a variable r.f. power source (such as a transmitter, or transmitter and switchable attenuator); (b) a dummy load equal to the coax surge impedance (typically 50-Ohms for RG8/U and RG58/U); and (c) a means of measuring r.f. power flowing through the coupler — either the wattmeter or r.f. probe described earlier can be used. The initial step is to identify which coax receptacle corresponds to the input side of the coupler for the forward switch position. With dummy load connected to one jack and transmitter to the other, set meter adjust resistance R3 to near-maximum, apply power, and then adjust R3 for a half-scale indication on the meter. Switch between forward and reflected positions — the one providing the higher reading senses forward power with the present connection of transmitter and dummy load. The connections for the switch can be reversed to coincide with the input/output jacks. Next, nulling can proceed. This involves adjustment of C1 and C2 to produce C3 sample voltages that are equal to those across R1-R2.

(A) Adjust transmitter output to the maximum power to be measured with the meter as indicated on either the calibrated wattmeter or r.f. probe, then adjust R3 for a full scale meter reading in the "forward" position.

(B) Switch to the reflected position and adjust C1 (transmitter input end of L2) for minimum reading. Switch to forward and readjust R3 for full scale reading. Redip in reflected position.

(C) Reverse transmitter and dummy load connections, and with the switch in the forward position, adjust C2 (dummy load side of L2 in step A) for a null in meter reading. Switch to reflected and readjust R3 for full scale meter reading.

(D) Repeat steps A-C. Bilateral operation is obtained when the meter reads the same power in both directions (i.e., transmitter connected to input jack and forward position, transmitter connected to output jack and reflected position. It may be necessary to repeat A-C several times to produce bilateral balance. If matched R1-R2 and D1-D2 are used, the coupler should be nulled first time through.

Once the nulling is completed, the meter dial face can be calibrated. If the calibrated wattmeter described earlier is used, this is simply a matter of setting transmitter output for a given power readout on the wattmeter scale, and then marking and numbering that power line on the in-line wattmeter scale. Or, cross reference in-line meter readouts in microamps vs watts in tabular form, as described for the wattmeter. Finally, check the Breune in-line wattmeter for frequency insensitivity. Feed equal amounts of power through it on 3.5 MHz and 28 MHz — readings should be equal. If desired, a separate SWR scale can be included on the new meter face.

VI. SWR Begins at the End

Let me close this book with a few comments intended to put an end to any mistaken notions that newcomers may have about the importance of the highly touted, frequently noted and almost always misunderstood bugaboo called “SWR” (standing wave ratio), which is defined as the ratio of reflected wave components to incident wave components. Despite the fact that everything ever written on the subject of transmission lines and antennas (except a very few well-informed pieces) tosses SWR around to prove one thing or another, the simple truth of the matter is that SWR does not provide data about (1) the efficiency of an antenna, (2) the amount of power that is either radiated or wasted, (3) the antenna’s input impedance, (4) an antenna’s resonant frequency, (5) the effects of “tuning and pruning” adjustments, (6) the broadness of the antenna’s bandwidth (unless special broad banding techniques have changed it into another antenna), (7) the best height for whatever purpose, (8) the best length of coax feedline to use, (9) the best piece of coax to use, (10) the best orientation for the antenna or (11) how much power is overheating the final amplifier (see my next book for items 12-232).

On the other hand, a change in SWR on the same antenna over a period of time can reveal deterioration in (1) the condition of coax cable feeding an antenna and (2) solder joints at both ends of the coax; a change can reveal (3) an increase in harmonic output from the transmitter, (4) a change in the height of the antenna, (5) a modification in the environment of the antenna and a few other factors. The paradox is: when the SWR gets lower, system loss has probably increased with a resulting decrease in efficiency, although this is not always the case. But it is true when a balun is inserted between line and antenna and the SWR drops. A complete discussion of all the relevant theory as it applies to QRP operation requires a book in itself, but a close study of the **ARRL Antennabook** will introduce the newcomer to the subject. A few points will have to suffice here to alert the newcomer to the essentials.

(1) All power fed into a transmission line is eventually radiated by the antenna, except for the amount lost in repeated journeys along a mismatched line. Power loss in the line is predictable by coax specs published by manufacturers. With SWR’s under 3:1, this SWR-related loss is negligible when high-quality coax is used in the h.f. spectrum. It is a simple matter of proportions. The incident wave travels along with a power far greater than that contained in a reflected wave in a line exhibiting a 3:1 SWR. The significant line loss occurs in the incident wave’s first trip down the line. No portion of the reflected power re-enters the transmitter. It is all re-reflected toward the antenna.

(2) The SWR on the line results entirely from the mismatch of coax surge impe-

dance and antenna input impedance. Antenna impedance is dependent upon numerous factors — element electrical length, feedline insertion point on the element, height above ground, and mutual coupling into environmental conductors, among others. Antenna impedance is changed when any of these factors changes. However, nothing can be done about line SWR anywhere back from the feedpoint. Should the QRP'r desire to eliminate every possible fractional dB of loss including SWR-related loss, the SWR on the line can be brought down to 1:1 by the use of stub matching at the antenna feedpoint. If a QRP rig experiences difficulty feeding a line with a particular SWR, the insertion of a transmatch between rig and feedline will permit transformation of line input impedance to transmitter load impedance and produce a perfect conjugate match ($SWR = 1:1$).

(3) The SWR is constant at all points along the line. Any change of SWR reading with a change of measurement point indicates a problem with the SWR meter or measurement technique. While it is true that antenna input impedance repeats itself at every exact half-wave point along a line because of traveling wave behavior, there is no point to taking SWR measurements only with half-wavelengths of feedline. A directional coupler in-line wattmeter correctly adjusted to the feedline surge impedance will read the same SWR anywhere along a feedline. The only difference between a reading at the antenna terminals and the transmitter end of the feedline is that caused by line loss.

(4) The SWR reading does not reveal antenna input impedance, which is a complex quantity consisting of a resistive and a reactive component. An "RX" or "Z" or "antenna" bridge is necessary to separate input impedance into resistive and reactive components.

(5) The lowest possible SWR occurs when no reactive component is present in antenna input impedance, and this is at the resonant frequency of the antenna. However, even the minutest change in frequency introduces a reactive component which rises very rapidly. This lowest SWR for a dipole connected to 52-Ohms coax, for example, is about 1.4:1, assuming that dipole input impedance is around 70-Ohms. Raising or lowering the dipole affects its antenna impedance, and a height probably can be found that will drop it to 52-Ohms and a 1:1 SWR. But there is nothing to be gained from this. A perfectly resonant, perfectly matched antenna will not radiate a significantly greater amount of power than one operated considerably off resonance with a 3:1 SWR, provided high quality coax is used.

(6) Since antenna impedance is dependent upon environment and the actual impedance is measureable only with an "RX" or "Z" or antenna impedance bridge, the use of an SWR meter in attempting antenna adjustments is foolhardy. Cut the antenna to formula specs, use high-quality feedline and hang it just like that. If a yagi or quad is being adjusted, reliance on an SWR meter is worse than foolhardy. Their design is based upon mutual coupling of elements which automatically modifies element input impedances and driven impedances and an SWR meter simply can't begin to sort it all out. Either adjust to formula specs and hang it, or proceed with an impedance bridge and field strength meter.

(7) In considering an antenna discussed in the magazines, look with suspicion on any that includes an SWR curve that is flatter across the band than basic calculations indicate it should be. Better yet, ignore the SWR comments. Similarly, distrust any "miniaturized" horizontal antenna which exhibits a reduction of more than about 20% in length vs a half-wavelength. It will probably be inefficient enough to make QRP frustrating. This goes for one frequently advertised "mini" which, when compared to a dipole, produced field strength readings 3dB lower than the dipole. However, verticals over extensive groundplanes (45 or more radians) can be shortened to incredibly small sizes and still match the performance of a full quarterwave vertical.

The theory underlying the above points is not included here, but a close reading of the **ARRL Antennabook** will lead to a more complete understanding. One problem with that book is that it isn't addressed to the newcomer — you have to dig. The classic work on the subject of SWR, unfortunately, has never been gathered into a book, but if the newcomer has access to QST's from the mid-70's, by all means borrow the issues noted, xerox'em and study them for a year or two. I am referring to M. Walter Maxwell's (W2DU) "Another look at reflections," (QST, April, June, Aug., Oct., 1973; Dec., 1974). **Believe me, there will never be a time when a QRP'r knows enough about antennas.**

Finally, I hope that this book, meager and flawed though it may be, will lead readers to an ever improving experience of The Joy of QRP! See you on the bands,
73, Ade W0RSP

QRP FIELD DAY Trophy Winners

YEAR	STATION	QSO's	SCORE
Five Watt Category			

1970	K40CE	220	1470
1971	WA6ABP	137	1175
1972	W7DRA	55	562
1973	WA5WY0*	79	1098
1974	W0IYP	439	2748
1975	WB8OSM	220	1470
1976	K6TG	128	918
1977	N2AA	389	2790
1978	WA4IAR	442	2804
1979	WD5BKO	287	1872
1980	K1JX*	741	9042
1981	N4BP	999	6144
1982	N5EM	259	1704
1983	WA0VBW	435	2760
1984	N4BP	1046	6426

*One-watt entries, score adjusted to current x8 multiplier.

One Watt Category

1981	K5ENH/0	239	3018
1982	No Entries		
1983	N0BYC	241	3042
1984	W8ILC	425	5250

Milliwatt Certificate Winners -1984-

KN1H John Collins: FD, 2nd

QRP-ARCI QSO Parties -Spring-

W5LXS	1st Place
KH6CP/3	2nd
G4BUE	3rd
W3TS	5th

<u>-Fall-</u>	
W5LXS	1st Place
WB5KFC	2nd
WB8VGE	3rd
AA4CO	4th

QRP FIELD DAY Club Standings

#	STATION	YEAR	QSO's	SCORE
1	N4BP	1982	1170	7170
2	K8BX	1981	854	5274
3	K9NG*	1984	418	5166
4	N6UU	1984	731	4536
5	K8IF	1979	732	4488
6	N2RI	1983	699	4344
7	N5AF	1982	685	4260
8	K8IF	1982	684	4254
9	KN9W	1983	643	4008
10	W2LZ	1983	637	3972
11	AC2U	1981	627	3912
12	N2RI	1982	625	3900
13	W3TS	1984	597	3732
14	WB9JVX	1982	584	3654
15	K8IF	1984	568	3558
16	N2RI	1981	555	3480
17	W2LZ	1984	512	3222
18	K8BX	1980	378	2985
19	KB8GC	1979	437	2772
20	KM8X	1981	407	2595

DXCC QRPp Trophy Winners (See inside rear cover for list)

65	G4JFN	Robert Hudson	5/84
66	WA9FWO	Frank Kolar	8/84
67	ON4QX	Louis Berge	10/84
68-SSB#16	KF4S	G.L. Murphy	1/85

DXCC Milliwatt Trophy Winners

9	KH6CP/3	Zachary Lau	10/84
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Preface to Second Edition (August, 1997)

The Joy of QRP: Strategy for Success was first published in 1984 in order to provide newcomers and veterans alike with the basic theory and information necessary for successful QRP operation. At that time, we were at the bottom of the sunspot cycle. Little did we suspect that a fantastic cycle was about to begin, providing the best-ever conditions for QRP operation since the late 1950's. In fact, conditions improved to the point that earning the DXCC QRPp Trophy became routine, so much so that we had to discontinue the program in 1989 after the 85th trophy had been awarded. The objective of the program had been achieved: to demonstrate to the world that 5-watts r.f. output and a decent antenna, in combination with QRP savvy, was all that was needed for intercontinental two-way communications. Those of you who have read **The History of QRP in the U.S., 1924-1960** know that the early pioneers like Robert S. Kruse and C.D. Maclurcan attempted to make exactly the same point to embarrass the "watt-hogs" and "ether burners" into a more sensible use of power. Unfortunately, an S9+50dB signal that "clears the frequency" is still the ideal of a great many radio amateurs.

But a dramatic change has occurred in the past quarter-century. The dogged persistence of QRP'rs, fed by the exhilaration of "getting through" with a few watts, has produced an enduring and visible movement in the world of amateur radio. The ease of succeeding with QRP during the peak years of the last cycle drew a great number of operators into the QRP ranks. As result, the world of QRP has expanded beyond our fondest dreams. When Mike Czuhajewski (WA8MCQ) and I began publishing **The Milliwatt: National Journal Of QRPp** in 1970 (see pp. 16-17), we could find only 40 or so QRP'rs for the subscription list. By 1975, the list extended to over 800 QRP'rs in more than 40 countries. QRP clubs began to appear: the first edition of **Joy of QRP** listed a dozen such organizations in 1984, and the list has continued to grow. (See below for details.)

That QRP has become a widespread "grassroots" movement as envisioned by F. E. Handy (W1BDI) and E.L. Battey (W1UE) in the 1930's (see **History of QRP**, Chapter 7) is clear from the formation of local and regional clubs under the umbrella of the national QRP-ARCI here in the U.S. In other countries such as the U.K., geography permitted members of the national G-QRPC to meet relatively frequently at various ham events. The G-QRPC was a club in a very real sense -- an organization where QRP'rs met in person to "ragchew" about the latest antennas, greatest contacts, and newest rig designs. Here in the U.S., I'd been trekking to the Dayton Hamvention during the 1970's to present a QRP Forum to 20-30 attendees, many of them **Milli-watt** folks. With the critically important transformation of the QRP-ARCI from a 100-watt club to a genuine 5-watt QRPp club in 1980 (see p. 18), the QRP-ARCI took over the Dayton operation and the forum began to expand. By 1996, the club reserved a floor of the hotel and rented the ballroom for a sold-out all-day forum for 100 pre-registered QRP'rs. Hundreds of other QRP'rs attended the annual Banquet as well as hospitality suite, regional club, and QRP vendor activities. Amazing! In the 1970's I could not even have imagined a "sold-out" QRP Forum lasting a full day with a long list of presentations.

Likewise, since the original "local chapter" club, the MI-QRPC, was founded in 1978, the concept has flourished due to the spread of QRP operation. Many publish **Milliwatt**-like journals which provide valuable information about operating as well as construction projects. In this area, several clubs have undertaken design projects and made available, at cost, excellent

QRP rigs in kit form. The NorCal QRP Club's meteoric rise since its inception in June 1993 illustrates how the formation of such a club can render the grassroots QRP population suddenly visible. By December 1994, membership had risen to 900, the majority in the region, but with many non-locals. A QRP Forum at the ARRL Pacific Division Conference drew a standing-room only crowd of 350! By March 1995, membership had risen to 1100; in mid-1997, it stands at 2300! NorCal's two kit-projects, the NorCal 40 and Sierra, were so successful that Wilderness Radio was formed by Bob Dyer (KD6VIO) to market them after the club's production run was exhausted. The NorCal quarterly **QRPP**, edited with tireless dedication by Doug Hendricks (K16DS), runs about 70 pages packed with full-blown construction projects as well as articles, notes, and reports beneficial to QRP operators.

But one of the most exciting developments in the QRP world could not have happened until very recently with the rise of the Internet and World Wide Web. The QRP-L Club group on the Internet (*QRP-L@LEHIGH.EDU*), founded by Chuck Adams (K5FO), provides an opportunity for about 3000 QRP'rs to exchange ideas and information on a daily basis. Getting advice, trouble-shooting hints, or specs for an IC-chip no longer requires days or weeks of research and correspondence. The posting of a question by a puzzled newcomer to QRP elicits a flurry of responses almost instantly. It is no exaggeration to say that QRP beginners "never had it so good". Similarly, WEB home pages are cropping up and have become a valuable source of information. Most of the QRP clubs have WEB-sites at present, each with links to others: the Alaska QRP Club at <http://www2.polarnet.com/~akqrp> cross-links about a dozen other clubs (such as the QRP-ARCI at <http://www.duke.edu/~djohnson/arci.html>), personal home pages, and all the commercial kits/parts suppliers. Clicking on the Dan's Small Parts icon allows you to search for and order that 5.1pf NPO for a v.f.o. circuit or an SBL-1 diode-ring mixer. The Wilderness Radio icon leads to descriptions, prices, and order forms for the NorCal 40 and Sierra transceiver kits. It would have been difficult to imagine over a dozen QRP commercial sources back when **Joy of QRP** was published, let alone the ability to browse their catalogues, read descriptions and spec sheets, and order QRP stuff on the spot! One of the most exciting developments for me, personally, can be found at <http://www.worldradio.com>. The **Milliwatt** icon -- an image of the earliest hand-drawn logo of **The Milliwatt** with the announcement that the full run of 33 issues is available on CD-ROM from Tom Arvo (WA8DXD). Every QRP'r ought to have it! This chokes me up every time I click! The memory of the countless hours I spent corresponding, editing, typing, photographing, and laying-out those issues overwhelms me when I realize that **The Milliwatt** lives again!

Propagation.

Perhaps the most valuable WEB resource for QRP'rs, especially DX'rs, consists of a variety of current propagation data and visuals. Beginners should read pp. 28-29, 31-41, 111-112, and 115-121 carefully to gain an understanding of how a complex set of factors determine whether or not a signal of a given frequency can traverse a path of a given distance at the vertical angles covered by the maximum lobe of radiation from an antenna, given the time of day and the current state of the ionosphere. When **Joy of QRP** was written, the only source of basic ionospheric data was an "800" number to "Dial-a-Prop" where the current SSN (smoothed sunspot number), 10.7cm flux, and A- and K-index data was recorded.

Several types of propagation resources are available on the WEB. An idea of how the cycle is progressing can be gotten from the monthly graphs of the 10.7cm flux, SSN, Kp, and Ap indices at:

www.ngdc.noaa.gov/8080/production/html/SOLAR/indices_frames.html
where you select the month and year; the 3-day forecast (10.7cm flux/SSN) is at: <http://www.ips.gov.au/asfc/current/index.html>

The current (two weeks) 10.7cm solar flux data (see p. 29) is available at:

<http://www.funet.fi/pub/dx/text/solarreports/www/flux.htm>

Change ["/flux.htm"](http://www.funet.fi/pub/dx/text/solarreports/www/flux.htm) to ["/cyclept.htm"](http://www.funet.fi/pub/dx/text/solarreports/www/cyclept.htm) for up-to-date cycle data. To wit, Cycle 22 bottomed in October, 1996, and Cycle 23 is very slowly on the uprise, although 10.7cm flux levels are stuck in the low 70's. Thus, a certain degree of "poetic justice" accompanies the re-publication of **Joy of QRP** because it was written at the bottom of Cycle 21 specifically to provide beginners with the in-formation necessary to get through the "tough times". If a beginner can learn enough about manipulating antennas, bands, operating times, and expectations to make QRP efforts successful and enjoyable during the bottom of the cycle, there will be one more very happy and proud QRP'r during the peak years! A basic principle cannot be restated too frequently: the key to realistic expectations is knowing the relationship between the antenna and the ionosphere. Unless this is understood, terrible frustration can result. The following resources are helpful. A current-time grayline world-map is at:

http://www.ips.gov.au/papers/richard/day_night.html

Local U.S. conditions can be seen in the current MUF map for N. America at

<http://www.ips.gov.au/asfc/current/usmap.html>

This map is useful enough for estimating the chances of working a transcontinental path on 14 Mhz or making a short 600-mile hop on 7 Mhz with a low antenna in the evening. Another site of potential interest to QRP'rs provides a simple graph of MUF and LUF for a specific ionospheric path, given the SSN, the month, and the sending/receiving locations and their coordinates. The data input form is at:

<http://itre.ncsu.edu/radio/mufluf.html>.

The coordinates for the locations can be gotten from the cross-linked prefix list of countries and states by exchanging ["/atlasinfo.html"](http://www.funet.fi/pub/dx/text/solarreports/www/atlasinfo.html) for ["/mufluf.html"](http://www.funet.fi/pub/dx/text/solarreports/www/mufluf.html). The sunspot number can be found at the ["http://www.funet.../www/flux.htm"](http://www.funet.fi/pub/dx/text/solarreports/www/flux.htm) site noted above.

However, for the serious QRP DX'r, the most fantastic, incredible development on the WEB is the near-realtime **MUF(3000)** contour world-map available at:

<http://solar.uleth.ca/solar/www/realtime.html>

which contains an explanation of how the map is interpreted for h.f. radio operation. I was stunned the first time I pulled up this map -- it was impossible to comprehend the enormity of this new reality. Back in the mid-1980's when I was researching and writing **The QRP'rs Guide to Transmission Lines/Antennas, Propagation and DX'ing** (never published), it was necessary to locate years-old soundings data in scientific publications for detailed contour maps of the F-region critical frequencies (**foF2**) and the **MUF(3000)** -- a years-old snapshot of the ionosphere that was interesting to the scientist but not useful to a QRP DX'r who needs to know the chances of a QRP signal reflecting off the ionosphere from point A to B, *now!* All that has changed, and how! This MUF map is updated every 30 minutes, so we can actually look at the ionosphere in near-realtime and decide on which targets are actually reachable and which are not worth calling. The **MUF(3000)** map can be accessed directly at: <http://solar.uleth.ca/solar/www/realtime.gif>. A valuable

feature of the map is that it includes the position of the current grayline zone, i.e., the global areas making the day-night transition. DX'rs have long tried to capitalize upon this transitional state of the ionosphere for openings to usually unreachable DX locations.

Re: SWR Begins at the End - Further Reflections.

I ended the first edition with a section stating the basic principles regarding SWR for good reason: newcomers must get one thing straight in order to deal with real antennas that get out: *SWR is the least significant factor in determining whether an antenna is correctly tuned and operating efficiently.* Unless a perfect match exists between feedline surge impedance and antenna input impedance at the feed-point, the transmission line *always* will exhibit standing-waves. As the operating frequency moves above or below the resonant frequency of the antenna, the SWR automatically and inevitably increases. Two kinds of SWR loss occur.

1). The minimum amount of SWR loss that results depends upon the frequency of the r.f. signal, the magnitude of the SWR, and the inherent loss-factor of the transmission line feeding the antenna. Transmission-line loss results from the ohmic resistance of the conductor and the type of the dielectric employed. A larger conductor (e.g., #12 vs. #24) exhibits a greater surface area and hence less ohmic resistance. Foam dielectric is less lossy than the dielectric used in regular coax, and the air dielectric in open-line exhibits virtually no loss (only the spacers absorb power). In coax, the shield-braid exhibits a loss component: although 97% shield-braid coax is more expensive, it does reduce loss just a bit. In choosing a transmission line for a particular installation, the QRP'r should seriously take the loss-factor into account. For example, the cost differential between expensive polyfoam-dielectric RG-8/A and 300-Ohm tubular TV twinlead is considerable and the usual economic formula applies -- "you get more for your money". However, in this case, "more" equates to "more line loss"! The attenuation in decibels per 100-ft. vs. frequency for several types of transmission lines clarifies this point:

Type	Zo	3.5 Mhz	7 Mhz	14 Mhz	21 Mhz	28 Mhz
RG58/A	53	0.68	1.0	1.5	1.9	2.2
RG58 Foam	50	0.52	0.80	1.1	1.4	1.7
RG8/A	52	0.30	0.45	0.66	0.83	0.98
RG8 Foam	50	0.27	0.44	0.62	0.76	0.90
TwinLead	300	0.18	0.28	0.41	0.52	0.60
Tubular TV	300	0.07	0.25	0.39	0.48	0.53
Open-Line TV	450	0.028	0.05	0.09	0.13	0.17

Several observations. (1) Note that the increased diameter of RG8 (0.405-in.) vs. RG58 (0.195-in.) decreases the loss figure by 50% or more because of the larger surface areas of shield-braid and conductor. RG8 is more expensive, much bulkier, and hence not attractive for field or portable operations. However, for the home QTH, RG8 is preferable, even for runs shorter than 100-ft (loss is directly proportional to length). The actual improvement in signal strength would be considered "negligible" in the QRO world. However, the savvy QRP'r aims at eliminating as much loss as possible -- a 400-mw or even a 2.2-w signal often can use an extra 0.3dB when awash in waves of QRN or QSB. We all have been in situations numerous times when just a tiny bit more audio signal at the noise threshold would make copy possible. In practical terms, for example, a 50-ft run of RG8 on

14Mhz could provide that extra bit of readability compared to RG58. (2) Note that the foam dielectric is superior in regard to the two types of RG8, but not by much. However, the difference is more significant for the two types of RG58. If RG58 must be used, especially on the high bands, the foam dielectric is worth the extra expense. Sources for high-quality coax are Nema Electronics (p. 76) and Radio Works (<http://www.radioworks.com>; 800-280-8327). (3) High impedance twinlead transmission lines are inherently less lossy than coax (the current component of the traveling wave is smaller at 300-Ohms than at 50-Ohms). While "open-" or "ladder-" line is awkward to work with at times, it is ideal for long runs in permanent installations. (Radio Works carries several types of "ladder-line".) Tubular TV or flat foam-dielectric twinlead is the best choice for normal situations; be sure to check the loss-figure if possible. Otherwise, shop around for the twinlead with the largest-diameter conductors. These balanced feedlines require an antenna tuner for matching to a QRP transmitter, but this produces a beneficial side-effect -- multiband capability with a single antenna. However, *QRP'rs usually fail to appreciate the fact that an antenna tuner should be used with coax as well.* The typical output filters employed in QRP rigs are not flexible matching circuits but low-pass or band-pass filters with a fixed 50-Ohms output impedance. They cannot be adjusted to match the transmitter to a line exhibiting an SWR (always present). Any SWR on the line changes the line's input impedance from its nominal 50-Ohms surge impedance to some other dynamic value exhibiting reactive components. A tuner is required to cancel those components as well as transform the actual dynamic line impedance to 50-Ohms.

As explained in section (1), p. 149, SWR loss is "negligible" in comparison to the major loss incurred by the incident wave. However, this depends upon the transmission line loss-figure and the magnitude of the SWR. For example, if 100-ft. of RG58/A exhibits an SWR of 2:1 on 14Mhz feeding a dipole, an additional loss of 0.24dB is incurred due to SWR, for a total of 1.74dB total loss. In contrast, RG8 Foam would exhibit a total loss of 0.76dB in the same situation. Assuming a low impedance antenna such as a dipole, open-wire would exhibit a high SWR of about 6:1, but the total loss would amount to only 0.1dB or so. SWR loss is indeed real, but the choice of transmission line can minimize its impact.

2). Additional SWR losses can occur because of "lossy" physical aspects of the installation. QRP'rs often mistakenly make the association "tiny rig = tiny power = tiny wire" when installing antennas. The simple fact is that "tiny wire" causes a significant amount of loss. R.F. current flows only on the surface of the wire, so resistance is inversely proportional to surface area -- #28 wire has a lot less surface area than #16 and much greater r.f. resistance. For example, at 3.5 Mhz, a halfwave of #28 exhibits about 10-Ohms vs. 4-Ohms for #16. The radiation efficiency of the antenna is the ratio of incident power radiated into space vs. that which is dissipated in the wire's r.f. resistance. Given an antenna radiation resistance of 70-Ohms, the #28 loss is about 12% vs. 5% for the #16. (Radio Works carries several sizes of stranded and copper-clad antenna wire.) As with feedlines, antenna elements carry incident and reflected wave traffic: multiple journeys are necessary for dissipation of all power in the incident wave and cause additional loss. In short, *"be the rig ever so tiny, let the wire be thick and hardy."*

Corroded solder joints in coax connectors and feedline-antenna connections are virtual resistors burning energy from both incident and reflected waves. Hence, care must be taken during assembly. The typical soldering

iron used by QRP'rs for rig-building simply will not heat a coax connector enough to produce a good solder joint. Experience shows that a butane torch with soldering tip saves a lot of time and gets the job done right. Similarly, the connections between feedline and wire antenna elements should be soldered even though a tight splice-wrap seems adequate. This connection should be weather-proofed -- usually a heavy, tight wrapping of electrical tape will last a winter. Stress should be removed from the soldered connections by securing the feedline and antenna elements to some form of "T" junction support. Plexiglas, PVC, and other insulator materials are suitable.

Transmission lines employing some form of solid dielectric are subject to significant weathering deterioration (sunlight, freezing etc.) and should be replaced after 2-3 years, especially in hostile climates. Loss increases dramatically with such deterioration. A simple method of checking for line loss in coax employs an SWR bridge or in-line wattmeter (p. 145). Short the antenna end of the feedline and apply enough power to get a full-scale reading in "forward". Switch to "reflected": The difference between the two readings indicates the magnitude of loss. Line loss (approximately) is 3dB for a 3:1 SWR., 2dB for 5:1, 0.9dB for 10:1, 0.5dB for 20:1. If a measurement was taken before the feedline was installed, the amount of deterioration will be clear. With many fixed output-impedance QRP rigs, the high SWR will either zap the final or launch it into parasitic oscillations (P-ref is higher than P-fwd). Hence, wisdom suggests that the feedline be fed through a transmatch; first insert the SWR bridge between rig and transmatch and adjust for a 1:1 SWR. Then insert the SWR bridge between transmatch and feedline for the measurement. If a calibrated wattmeter is used, a full-scale deflection is unnecessary, since the SWR can be calculated according to:

$$SWR = (1 + (\sqrt{P_{ref}} / P_{fwd})) / (1 - (\sqrt{P_{ref}} / P_{fwd}))$$

In general, 75-ft of good-condition RG8 will barely show a difference between P-fwd and P-ref on 3.5 and 7 Mhz.

CLUB INFORMATION

QRP-L. Internet QRP-List Club. Subscribe to the QRP-L list by sending e-mail to "listserv@lehigh.edu". Leave the "Subject" line blank. Message body consists of the command and your name and call: "SUBSCRIBE QRP-L Nutty Qwerpr N9QRP". The confirmation message will contain a password and basic instructions for accessing the archives via File Transfer Protocol (FTP). About 3000 QRP'rs currently subscribe and exchange ideas, information, and answers to questions. The **QRP-L** Web-site provides access to a variety of materials at [<http://qrp.cc.nd.edu/qrp-l/index.html>]. Current QRP clubs news can be accessed by replacing the "[index.htm](#)" with "[clubinfo.html](#)" or clicking the link (applies to the following). "[qrpinfo/html](#)" contains links to three valuable resources: (1) a detailed list of updated information about the clubs on pp. 17-20 and those listed below; (2) The QRP Periodical List compiled by K4RNL - a bibliography of QRP printed resources; and (3) a link to the **QRP-L** FTP site where the archives of the e-mail postings on **QRP-L** can be downloaded. "[hamlinks.html](#)" provides a long list of links to clubs, commercial suppliers etc. "[pictures.html](#)" accesses the archive of digitized photos from QRP events such as Dayton. "[catalogue/index.html](#)" provides reference information about various commercial and club-kit QRP rigs.

AK/QRP. Alaska QRP Club. Bruce Hopkins (KL7JAF) home page manager. Join via e-mail form. Electronic newsletter *TUNDRA TELEGRAPH* posted on WEB-site or delivered via e-mail. Home page features comprehensive collection of links to QRP sites including commercial kits/parts suppliers [<http://www2.polarnet.com/~akqrp>]. **BMHA. Bicycle Mobile Hams of America.** Hartley Alley, Bicycle Mobile Hams of America, POB 4009, Boulder, CO 80306. (Phone 303-494-6559). *BMHA Newsletter*, 4 issues/year \$10 individual, \$15 family or foreign. **BC QRP. QRP Club of British Columbia** Derry Spittle (VE7QK) 1241 Mount Crown Road, North Vancouver, BC V7R

1R9 CANADA. Dues: \$5.00 Four Newsletters/year following each meeting. These are mailed to members and posted on the **QRP-L**. Quarterly lunch meetings alternating between the Lower Mainland and Vancouver Island [jds@freenet.vancouver.bc.ca].

QSCP. QRP Society of Central PA. c/o Cameron Bailey (KT3A) PO Box 173, Mount Wolf, PA 17347-0173. [KT3A@aol.com]. QRP Gazette", bimonthly, about 4 pages. \$5.00 for the newsletter. Serving the needs of local QRP'ers in Central PA. Sample Newsletters can be obtained from KT3A for an SASE. **Cleveland QRP Amateur Radio Club.** Bruce A. Wright (N8MWL), P.O. Box 14052, 410 Superior Ave., Cleveland, OH 44114-9998. **CQC. Colorado QRP Club.** Rich High (W0HEP), 740 Galena Street, Aurora, CO 80010-3922. (303-344-1220; 344-0741). Membership info: c/o Mark Meyer, 14153 West First Drive, Golden, Colorado 80401. *The Low Down*, bi-monthly newsletter, US: \$10.00. Current QRP news is e-mailed to members. Home page: [<http://www.mtechnologies.com/mthome/cqc.htm>].

Durham Region QRP Club. c/o Jim Wilson, 788 Edgewood Road, Pickering, Ontario L1V 2Z9, CANADA. Meets 3rd Tuesday of the month, at Centennial College, Progress Campus, in Scarborough, Ontario (Highway 401 and Markham Road), meeting in the electronics lab on the 3rd floor, "D" Wing, 7:30 p.m. Informal, with a member-selected topic announced in advance. CW net Wednesdays, 8:00 pm local time, 3535 kHz. **NE QRP. The QRP Club of New England.** William McNally (AE1D), 7 Blueberry Road. Windham, NH 03087. US: \$10 new member; outside USA pse add \$5. Club quarterly 72 renewals are from September to December. **NJ-QRP. New Jersey QRP Club.** Vince Passione (WA2ECP), 1 Courtney Way, Red Bank, NJ 07701. (609) 520-4803. [vincep@dj.com]. Monthly "show and tell" at varied locations in New Jersey. **NorCal QRP. QRP Club of Northern California.** Home page: <http://fix.net/norcal.html>. Doug Hendricks (KI6DS), Editor of *QRPP* [dh@deneb.csustan.edu]. Membership info, *QRPP* quarterly subscriptions to: Jim Cates (WA6GER), 3241 Eastwood Rd., Sacramento, CA 95821; US: \$10; Canada: \$15; DX: \$20 (airmail) Make checks out to Jim Cates, not NorCal. **NEIQS. NorthEastern Illinois QRP Society.** Don Kozlovsky (KE9GG), 28 W 256 Purnell Rd., West Chicago, IL 60185. *NEIQS Newsletter*, (SASE) [nwqrp@scn.org]. **NW QRP. The NorthWest QRP Club.** Bill Todd (N7MFB), PO Box 354, Bay Center, WA 98527. To join US:\$10 CAN:\$12 DX:\$15. **The NWQ Newsletter**, bi-monthly, about 8 pages. No dues. [<http://www.scn.org/scripts/menus/nwqrp/nwqrp.menu>]. **NorTex QRP (NQC). North Texas QRP Club.** Chuck Adams (K5FO) [adams@chuck.dallas.sgi.com]. **OK QRP. Oklahoma QRP Club.** Don Kelly (K5UOS), 703 West 8th St. Edmond, OK 73003. \$10, *Oklahoma QRP*, quarterly. **SLQS. St. Louis QRP Society.** c/o Keith Arns (KC0PP), 2832 Penbrooke Lane, St. Charles, MO 63301. \$12.00. *The Peanut Whistle*, monthly. Third Wednesday of each month, at Florissant Valley Community College. **9A-QRP. 9A-QRP Club.** Mladen Buzic (9A3FO), Franjevacica 5, 42220 Novi Marof, CROATIA. (042 612 400). **EA QRP Club** (successor of EA8-QRPC). Secretaria del EA QRP Club, Sr. Miguel Montilla Guerrero (EA3EGV), Paul Abad 15-3-1, E-087207 Sabadell, Barcelona, SPAIN. \$12; elsewhere: \$15, *QU-R-PE*, in Spanish, quarterly. **GW QRP. GW QRP Club.** Leighton Smart (GWOLBI), 33 Nant Gwyn Trelewis, Mid Glamorgan, Wales, U.K. **QRP Club of Ireland.** Billi Ryan (EI8BC), c/o Marino Institute of Education, Griffith Avenue, Dublin 9, IRELAND. **OK QRP. OK QRP Club.** Petr Doudera (OK1CZ), U 1.baterie 1, 162 00 Praha 6, CZECH REPUBLIC. Also, a Slovak QRP group has been noted: **QRP rubric**, Roman Vavro, Latoricka 15, 821 07 Bratislava, SLOVAKIA. 15 IRC's or \$10, DM 15, 5 GB Pounds. IRC's preferred. **OK QRP INFO (OQI)** quarterly, has English translations for most of the text, SPRAT-size, abt 30 pages. **U-QRP Club.** P.O. Box 100, Saransk - 31, RUSSIA 430031. Newsletter is in Russian. **UPDATES** to pp. 17-20. **QRP-ARCI.** \$12 U.S., \$14 DX, to: Mike Bryce (WA8VGE), 2225 Mayflowers NW, Massillon, OH 44647. *QRP Quarterly* included. **MI-QRP.** \$7 U.S., \$12 DX to: Membership Chairperson, Michigan QRP Club, 654 Georgia, Marysville, MI 48040. *The Five-Watter: The Quarterly of the Michigan QRP Club* included. **AGCW-DL.** Contact: Tom Roll (DL2NBY), Richard-Wagner-Str. 11, 90513 Zirndorf, GERMANY. **Benelux QRP Club.** Contact: Robertvan der Zaal (PA3BHK), P.O. Box 15, NL-2100 Heemstede, The Netherlands. **CW-QRPC-VK.** \$10 VK, \$14 DX, to: Kevin Zietz (VK5AKZ), 41 Tobruk

Ave., St. Marys, SA 5042, Australia. *Lo-Key* quarterly included. **EA8 QRP-DX Club** replaced by **EA QRP Club**. **G-QRP Club**. \$12 U.S., contact: Mike Kilgore (KG5F), 2046 Ash Hill Rd., Carrollton, TX 75007. *SPRAT* included. **JARL-QRP Club**. Contact: Takahisa Masuzawa (JH1HTK), P.O. Box 9, Tsubata, Ishikawa, 929-03 Japan.

QRP NETS. Most of the QRP NET schedule noted on p. 25 is outdated. Although listening and calling on the QRP Frequencies usually produces contacts fairly regularly, checking into a QRP NET guarantees that other QRP'rs are listening for weak signals and if your rig/antenna are actually working, you'll be heard. Some recent NET schedules follow. **NE QRP**, s.s.b. net, 3835kHz, Monday, 0200Z. **BC QRP**, s.s.b. net, 3729kHz, daily, 0300Z & 0500Z. **NW QRP**, 3720kHz, Monday, 0230Z; 10123kHz, Monday, 0200Z. **Knightlites**, 3710kHz, Sunday, 0230Z. **NEIQS**, 3560kHz, Thursday, 0230Z. **NW QRP**, 3710kHz, Saturday, 0730PST. **VE QRP**, 14060kHz, Sunday, 1900Z. **QRP ARCI** Nets: SEN, 7030kHz, Tuesday, 0100Z; GSN/GLN, 3560kHz, Wednesday, 0200Z; WSN, 3560kHz, Wednesday, 0300Z; NEN, 7040kHz, Saturday, 1330Z; TCSN (s.s.b.), 7825kHz, or 28332kHz, Sunday, 1900Z; TCN, 14060kHz, Sunday, 2300Z; **MI QRP**, 3535kHz, Tuesday, 2100EST & EDST. Check QRP-ARCI home page for contests and other activities.

Viking-5 Note. The p.c. board overlay for the single-band **Viking-5** in Figure 13 (p. 81) shows a confusing key-ground connection. One key-lead connects to the pad terminating the 33-ohm resistor, the other key-lead connects to the ground foil (left end of C1b). The p.c. board template for the single-band version (overlay in Figure 13, p. 81) is found on p. 77. The front cover photos show the two-band version with matching mascot. Since the publication of the first edition of *Joy of QRP*, both the *MPS-U31* (Q1) and the *2N5589* (Q2) have ceased production (as has the *MPS-U02* which has worked for Q1). I have not tested substitution transistors and cannot vouch that the following will work, but the circuit of the **Viking-5** was designed for wide variation in tolerances. (The basic circuit will work at lower power levels but L1 and L3 will require an extra turn or so for matching. Likewise, the output filter C2-C3-L4 will have to be redesigned for the new output level.) NTE Electronics cross-lists their *NTE302* for Q1 and *NTE347* for Q2 (NB: the *NTE347* must be rotated 180-degrees for correct B-C connections) (800-280-8327; http://www.nteinc.com/Web_pgs/Prodindex.html). The *MRF-476* (2SC2075) should serve as a replacement for the *MPS-U31*. However, the *MRF-476* uses the standard TO220-case pin-out (i.e., I-r, E-C-B), which is different from the *MPS-U31* (I-r, E-B-C), so be careful to correctly connect the leads. Dan's Small Parts (<http://www.fix.net/dans.html>) lists the *MRF-476* at \$3.50. Possible substitutions for the *2N5589* (Q2) include the nearly identical *MRF231*; the *ECG-347*; and an *MRF-472* should work also but the p.c.b. mounting pads will have to be modified. The *MPS6514* used in the v.f.o. circuits (Figs. 14, 17) is a small-signal plastic NPN. NTE cross-lists the *NTE123AP*; the specs are the same. A *2N2222A*, *2N3053*, *2N3866* or other small-signal type should work as well. See also HB Electronics (<http://businesson.com/HAMPARTS>).

Photos Note - p. 41. Upper-left: photo of the **Wattmeter** described on pp. 137-142, where meter-calibration resistor "Rcal" can be seen at the lower right corner. Upper-right: two photos (assembled, unassembled) of the **R.M.S. R.F. Voltage Probe** described on pp. 142-44. Bottom: the p.c. board template for the the full-size **Vackar V.F.O.** shown in Figure 15, p. 85. The p.c. board for the miniature version of Figure 16 is found on p. 77. A separate p.c. board template for the **Bruene In-line Wattmeter/SWR Bridge** described on pp. 145-149 was not reproduced: the overlay can be xeroxed and used since it is full-size.

Corrections - Rear Cover. The decision to publish a diplomatic reprint of the first edition as a historical document meant leaving everything intact, including typos and references on the rear cover to projects that did not materialize. These include **The QRP'rs Guide** and G4BUE's section of **The History of QRP**. **The History of QRP** was thus limited to the U.S. and whatever information was available about DX locations. The book was written to provide QRP'rs with a sense of their continuation of a tradition that stretches back to the very beginning of the vacuum tube era. We are not just a bunch of nuts tinkering around with low power rigs in the 1990's! We belong to a long line of radio amateurs from the 1920's, 1930's, and on to the present, who take seriously the proposition that "power is no substitute for skill and knowledge." We are not just members of this club or that, but rather, the latest wave of adventurous operators who choose to battle the ionosphere and QRN armed only with a few watts, dogged persistence, and operating savvy. Every QRP'r ought to read **The History of QRP** to comprehend this fact. The reactions of reviewers to the book follow.

New Books: History of QRP in the U.S., 1924-1960

The joy of being a QRPer results not only from building little rigs and bucking the QRM while operating. QRP purists extract satisfaction and pleasure from studying the history of low-power operating and the related challenges. **History of QRP** provides extensive coverage of the QRP movement in the U.S. from 1924 to 1960. As a writer of books and articles, I cannot help but view Adrian's research efforts in awe. His dedication to the objective while gathering archival data is obvious as you read the spellbinding chapters of this book. Certainly, Adrian would make a great curator of some future QRP museum. His grasp of the historical aspects of our flea-power pastime is impressive, to say the least. The chapters are (in order);

1. The K8EEG (now W0RSP) Story
2. Prologue to Exploration
3. QRP Pioneers on the Frontier, 1923-24
4. 1925: QRP Takes the Spotlight
5. 1926-27: Newcomers and DXers
6. 1930-41: Grass Roots vs. High Power QRM
7. QRP Gains Ground, the 1930's
8. QRPers' Story in Their Own Words
9. The Uprising of '37 - The Flea Power Association
10. 1945-60: Before the Transistor
11. 1954-60: Milliwatts and Miles

The book is sprinkled with black-and-white photographs of old-time operators and equipment. My nostalgia was heightened by many of these illustrations. For example, Weiss shows a picture and schematic diagram of a WWII surplus mini plug-in unit, the BCR-746-A tuner. The diagram shows Barry Lindsey's (W4BIW) circuit adaptation that called for the addition of a 1S4 battery-radio tube, which was used to convert the tiny tuning unit to a QRP transmitter. When the ARRL staff tested this transmitter in 1947 ("A Bantam 1-Watter," January 1948 **QST**), they worked 22 stations in 10 states during a 12-hour period! How well I remember the excitement I felt when I bought my first BCR-746-A unit in 1946 for only 50 cents! Reading about it in Weiss's book brought back fond memories indeed.

This book should serve as a guidepost to what QRP operation is about, especially with regard to the thrills that accompany the use of homemade equipment. This part of Amateur Radio is missed by many of today's hams

who operate only with store-bought rigs. I recommend this book for your Amateur Radio library, even if you never become a member of the fast-growing QRP fraternity.

Doug DeMaw (W1FB), **QST** (May, 1988)

Rare Insight from a New Book: Exploits of Low Power Communication

Ade Weiss, W0RSP, champion of homebrew construction and low power operating, has compiled a history of low power communications exploits, telling the story behind the great communications records of this century. His most recent book reveals the circuits, the construction methods, and the operating techniques that produced the milestones. Each rare photograph tells more than ten thousand words. Better still, Ade captures the driving spirit behind the pioneers of ham radio, and captures the drama of the events by telling the story of the hams who did it, often in their own words. Every radio enthusiast, whether listener or ham, can benefit from this book. The fruit of Ade's tireless and painstaking research, it's more than a priceless reference, it's a monument to the dynamism of amateur radio. The book, **History of QRP in the U.S.**, contains over 70 priceless photographs and drawings and 200 pages of thrilling stories.

Jim Stevens (KK7C), AntennasWest

History of QRP in the U.S.: A NEW BOOK FROM W0RSP

Many radio amateurs in the UK will know Adrian Weiss, W0RSP, from his writings on QRP in the *CQ Magazine*, and from his fine book **The Joy of QRP**. Ade has recently produced another book with the mammoth title **The History of QRP in the U.S., 1924-1960**. The book traces the history of low power communication from spark transmission to early solid state designs. It contains well documented accounts of the major advances in QRP communication with special reference to work in the U.S. It is well illustrated with photographs and circuit diagrams of the equipment used by these pioneers of amateur radio. The book is a nice blend of good scholarship (W0RSP lectures in Shakespearean Literature at the University of South Dakota) and the "folksy" style we have come to know from Ade. The first chapter named "The K8EEG Story" describes his own early dabblings in amateur radio and the enthusiasm that has been with him to this day. This is a little gem of amateur radio writing! It shot me straight back to my early introductions to the hobby and revived the motivations and pleasures that have kept me active in the hobby for so many years. Throughout the rest of the book I enjoyed reliving the early trials and joys of keen amateurs working against the odds with little theoretical knowledge. This book is a must for those who enjoy finding out more about the pioneers of our hobby.

Rev. George Dobbs (G3RJV), **SPRAT** (Nr. 54, Spring 1988)

FOR YOUR QRP BOOKSHELF

When the author's Preface is dated August 10, 1987, you know it's current. And when that Preface is signed by Adrian Weiss (W0RSP), you know that you've got some well researched reading ahead. This latest of Ade's books -- **History of QRP in the U.S., 1924-1960** -- chronicles QRP in the U.S. and that chronicle certainly parallels, and indeed becomes, the development and growth of U.S. amateur radio itself. If you think that our QRP interest is an interest in a facet of amateur radio that just started yesterday, think again! **History** gives us QRPers a sense of belonging and gives us an extended heritage. It is technical and yet it is very academic. It is something to warm the cold winter nights with good memories and it is something to fire the

imagination for today. If you were born between 1940 and 1945, Ade's Chapter 1 may move you to tears as he guides readers through memories of his own 'awakening' in the mid-fifties. **History** is 'crammed' with the photos and the schematics and the details and the specifics that blend together to tell the story of U.S. QRP from 1924 to 1960. Did the Heathkit AT-1 qualify as a QRP rig? What was the *Jewell QRP Contest* of 1926? **History** has the rigs and the people and the accomplishments. It is a **MUST** for your QRP bookshelf. The book is 200 pages and paperbound. It is similar in size and quality to **The Joy of QRP** and has the same print quality. Your money buys 11 chapters plus a Preface and an Epilogue, including 56 photos and 16 illustrations. Thomas A. Root (WB8UUJ), **The Five-Watter** (Sept., 1987)

The History of QRP in the U.S., 1924-1960 is available from MILLIWATT BOOKS, 526 N. Dakota St., Vermillion, SD 57069. \$15.00 (First Class) U.S. (\$10.00 Seniors), \$17.50 Foreign. While the supply lasts, 8 back issues of **The Milliwatt** are available at \$10. As noted above, all 33 issues are available on CD-ROM for \$25 from Arvo Communications, 1900 Howell Branch Rd., Winter Park, FL 32792 (arvo@arvo.com).

May this second edition help readers to greater success in their pursuit of the incomparable thrill, pride, and Joy of Qrp operating!

72/73, Ade Weiss W0RSP

Final DXCC Trophy List

<u>DXCC QRPp Trophy</u>				<u>DXCC MILLIWATT Trophy</u>			
65CW	G4JFN	Robert Hudson	5/84	9	KH6CP	Zachary Lau	10/84
66CW	WA9FWO	Frank Kalor	8/84	10CW	OK1DKW	Petr Doudera	5/86
67	ON4QX	Louis Th. Berge	10/84	11CW	N6QR	Adam A Menten	5/87
68-	KF4S	Gary L. Murphy	1/85	12CW	G4JFN	Robert Hudson	2/88
SSB#16				13CW	AA2U	Randy Rand	4/89
69	KT1H	Brad Hutton	3/85				
70-	CT4CH	Bengt G Johansson		<u>DXCC MILLIWATT 200 Plaque</u>			
SSB#17			5/85	2CW	GM3OXX	George Burt	3/88
71	KA3CRC	Thomas R Schmitz	5/85				
72CW	K2CL	Charles H Lloyd	8/85	<u>DXCC QRPp 200 Plaque</u>			
73-	NN4Q	Sam Burgin	1/86	7	NN4Q	Sam Burgin	1/86
SSB#18				8	AA2U	Randy Rand	4/89
74-	EA2SN	Jon Iza	5/86	9	KR2Q	Douglas Zweibel	4/89
SSB#19				10	SM0DJZ	Jan Hallenberg	3/91
75	G8PG	A D "Gus" Taylor	6/86				
76CW	OK2BMA	Pavel Cunderla	12/86	<u>5-Band DXCC QRPp Trophy</u>			
77CW	OK1DKR	Rudolf Kaderabek	1/88	1	AA2U	Randy Rand	5/89
78-	W2JEK	Donald C Younger	3/88				
HW8				(correction:			
79CW	GM4YLN	C Grierson	5/88	59	W6SKQ	Robert E Spidell	9/83
80	SM0DJZ	Jan Hallenberg	6/88				
81	KA1GPG	Jim Kueppers	6/88				
82	KV4B	Richard D Wilson	11/88				
83CW	NF5Y	Herb Spivey	11/88				
84	KR00	Jeff Elson	7/89				
85CW	G3IJV	R D Harvey	8/89				

DXCC QRPp Trophy Awards
(under 5-watts output)

#1	K4OCE	Robert Rosier	12/71	#45	WB4SXX	Bill Meacham	10/82
#2	W2GRR	Sanford Sandowsky	6/75	#46-	KK9Q	Michael Wendland	10/82
#3	K8MFO	Don Karvonen	2/76	SSB#12			
#4-	W6PQZ	John K Akiyama	4/76	#47	KH6CP	Zachary Lau	12/82
SSB#1				#48	JA6VZB	Toshi Moriyama	1/83
#5	N2AA	Eugene Walsh	5/76	#49	N8CQA	L T Switzer	1/83
#6	OA8V	Paul Wyse	5/77	#50	WB9WIC	Lawrence Schulman	4/83
#7	WA6SOV	Lee Williams	7/77	#51	AA2U	Randy Rand (son)	4/83
#8	G4BUE	Christopher Page	11/78	#52	K2RF	Henry T Rand	4/83
#9	OE1ZGA	Tom Gabbert	3/79	#53-	KF1H	Ronald D Morais	5/83
#10	WA2JOC	Wm. W Dickerson	3/79	Both Modes	#2		
#11	WB8IGU	Howard G Hawkins	7/79	#54	NN4Q	Sam Burgin	5/83
#12	VE1BQQ	Leon Fitzgerald	11/79	#55-	OE1SBA	Bruno Settingter	6/83
#13-	W6YVK	Everett D Willis	2/80	SSB#13			
SSB#2				#56	KH6OA	J Dean Paterson	6/83
#14-	K4RUG	Charles Hoffman	3/80	#57-	N1BZG	Fred Sterner	7/83
SSB#3				SSB#14, All	10 Meters	#2	
#15	W1PWK	Richard M Vacca	3/80	#58	WB8SP	Adrian Weiss	8/83
#16-SSB#4, Both Modes	#1--			#59	W6SKW	Robert E Spidell	9/83
	WA2JOC	Wm. W. Dickerson	3/80	#60-	VK3RF	Raymond F Miller	10/83
#17	VE5JQ	John Dudley	3/80	SSB#15			
#18-	N0AJZ	Lanny C Rather	4/80	#61	WB2IPX	Les Shattuck	10/83
SSB#5				#62	NF4Z	E Stuart Greg	11/83
#19	K0CDJ	William P Wilson	5/80	#63	K9PNG	James H Jones	12/83
#20	OK1DKW	Petr Doudera	6/80	#64	KR2Q	Douglas Zwiebel	4/84
#21	SM5CCT	Bengt Eriksson	6/80	--DXCC 200 QRPp Plaque Awards--			
#22	SM0GMG	Lars Mohlin	7/80	#1	N2AA	Eugene Walsh	12/78
#23	WA4LOF	Richard E Schier	7/80	#2	G4BUE	Christopher Page	12/80
#24	KH6HC	Tatsuro Suzuki	7/80	#3	WA4LOF	Richard E Schier	5/81
#25-	GM3RFR	Samuel S S Polson	8/80	#4	WA6SOV	Lee Williams	6/82
#26	K4TWJ	Dave Ingram	9/80	#5	WB8IGU	Howard G Hawkins	12/82
#27	K8DU	Al Bhar	9/80	#6	WA0VBW	Randal M Shirkbroun	5/4
#28-	K1MNR	Ronald D Morais	1/81	--DXCC 200 MILLIWATT Trophy Awards--			
SSB#7 (see #53)				#1-	W8ILC	Ronald Moorefield	6/78
#29	VK7NRT	Rai Taylor	2/81	SSB#1			
#30	AB0X	Michael Crabtree	3/81	#2	GM30XX	George Burt	12/78
#31-	WB9OAR	Dan Reimer	6/81	#3	G4BUE	Christopher Page	12/79
SSB#8				#4	KI4W	Margaret Williams	2/80
#32-	K2OQA	Edward A Borow Jr	6/81	#5	W4IV	Wm Montgomery Jr	11/81
SSB#9, All 10 Meters				#6	EA8EY	A Montero Martin	4/83
#33-	KB3PD	Richard Phillips	7/81	#7	JA1MCU	Jiro Manaka	4/83
SSB#10				#8	GM4ELV	Daibhidi Dhuglas	5/83
#34	AB0M	C L "Vern" Lang	7/81	--DXCC 200 MILLIWATT Plaque--			
#35	WA0VBW	Randal M Shirkbroun	9/81	#1-	W8ILC	Ronald Moorefield	4/80
#36	KM8X	Chris Hethorn	10/81	SSB#1			
#37--WB8CTC							
SSB#11							
#38	KB9JJ	Matt Teicher	12/81				
#39	N0ZA	Ross Harrell	12/81				
#40-	W9PNE	Brice Anderson	2/82				
Half-Century QRP Contributions							
#41	GM4ELV	Daibhidi Dhuglas	5/82				
#42	AD2Y	Michael Akiki	5/82				
#43	CX7BBB	Antonio Villano	6/82				
#44	VK4SS	Alan Shawsmith	7/82				

 * DXCC 300 MILLIWATT Trophy Award *
 * #1 All SSB#1 *
 * W8ILC *
 * RONALD MOOREFIELD 2/84 *



About the Author

First licensed as WN3COB in 1955, then K8EEG in 1957 and finally W0RSP in 1977, Adrian Weiss has long been an avid QRP'r. In addition to homebrewing and operating, his interest in QRP led to the founding of **The Milliwatt: National Journal of QRP**, published 1970-1975, and he has served as QRP Editor for **CQ Magazine** since 1974. Solid-state design, propagation and DX'ing, and QSO'ing other QRP'rs are his chief interests in amateur radio. In "real life", he holds a Ph.D. in English Renaissance Literature and derives his greatest professional satisfaction from teaching Shakespeare's dramas.

Coming Attractions

The History of QRP, 1924-1926, the story of the beginning of the QRP "way of life" back in the early days of amateur radio. Includes an expanded version of "The K8EEG Story," the author's account of his own beginnings in amateur radio and QRP, and detailed histories of QRP in the U.S. and England, with Christopher Page (G4BUE) as co-author.

The QRP'rs Guide to Transmission Lines/Antennas, Propagation and DX'ing, a detailed comprehensive examination of the subject of ionospheric propagation and its application in QRP operation, with special emphasis upon DX'ing.

Still available while they last: back issues of **The Milliwatt** at \$10 for a packet of 14 — a goldmine of QRP material by QRP'rs. Also, HW-8 owners will be interested in reprints of the author's series of articles about the unit at \$7, proceeds to support the Milliwatt DXCC Program.

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